EXPERIMENTS OF THE STRENGTH OF BOLTS AND SCREWS

BY

JONATHAN HUNTOON SAMUELS HODGSON
BERT ANDREW MILLER

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Jonathan Huntoon Samuels Hodgson and Bert Andrew Miller

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IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE

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H. F. Moore
Instructor in Charge

APPROVED: G. A. Goodenough

HEAD OF DEPARTMENT OF Mechanical Engineering

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**********INTRODUCTION*********

In this country very little has been done on the strength of bolt threads. A. L. King made some experiments on the tensile strength of screw threads, an account of which appeared in the American Machinist of August 12th, 1896. His work was confined to comparison of different types of thread made by other methods, which was the plan followed out in this thesis. His results showed that; (1) when subjected to plain tension the different types of screw threads were stronger than the plain bars of the same area of cross section by about fourteen (14) per cent, (2) no very marked difference in the strength of the different styles of threads appeared; the perfectly sharp groove, being slightly stronger than the others which were grooves of round and flat bottoms, (3) the weakening effect of the turning of the nut under stress was in the one inch bolts twenty per cent, and in the one half inch, about fifteen per cent, (4) in general, it may be said that the turning of the nut upon the bolt at rupture reduces the strength of the net section thirty per cent.

The object of this work is to give the comparative strength of three different kinds of threads, viz: die-cut, machine-cut, and rolled, using bolts one half, three quarters, and one inch in size for each make of thread. The tests were to determine the strength of bolt in static tension and the shearing strength of the thread. All cut threads were U. S. Standard, and the rolled threads were as nearly like them as was possible to get them.

The die and machine cut threads are the commonest type of thread and, are most used in practice. The die-cut, since it is cheaper, is used where workmanship and cost enter into consideration, while the machine-cut thread is adapted to work where accuracy and smoothness are required, regardless of the cost of production. The rolled threads are made extensively for track bolts and rough work where the size of the shank does not make an appreciable difference. The general practice does not seem to take into account the strength of the rolled thread but simply the cheapness of the bolt and the adaptability to rolling the form of bolt required.

********TEST PIECES AND TESTING********

The material for the bolts and threads of the die-and machine-cut type was ordinary soft steel bought in the open market. The specimens were obtained from different bars and as a result the ~~stresses~~ strengths were not the same in all cases. The stock, being cheap, was not uniform in size and it was due principally to this fact that the threads were not perfect in every case. The machine-cut threads were made as smooth as possible. No half-inch lathe cut bolts were tested on account of the difficulty in cutting so small a bolt in the lathe. The die-cut threads were turned out in the thread cutting machine in the shops of The University of Illinois. The dies were not very sharp but were as good as would ordinarily be found in practice. The rolled threads were obtained from the Oliver Steel and Iron Co. of Pittsburg, Pa. The process in the manufacture seems to be the passing of heated stock between two dies that move in opposite directions and at the same speed, thus causing the stock to rotate but not to have translation. The threads are simply squeezed into shape by diagonal thread forming projections on the dies which works the material so that its strength is increased. The nuts cannot be rolled in the small sizes. (3)

All of the specimens, except the rolled stock, were two feet long with each end threaded. One end was tested for tensile strength, the other for shearing strength of thread. The rolled stock was about eighteen inches in length with approximately the same number of threads. For the shearing tests the specimens were set up in a lathe and centred as nearly true as possible. The threads were then turned off at the root except for about two whole threads. Calculations showed that under ordinary stresses for mild steel that in the half inch bolts about sixteen hundredths of an inch was about all that would shear, while in the three quarters inch eighteen hundredths could be used, and for the one inch twenty-one one hundredths of an inch was necessary.

A system of classification of specimens was deemed necessary and the following was adopted. The identification mark gives the number of the specimen, diameter of the stock, and the kind of thread; as for instance, 2-3/4-M would mean specimen number two of the three-quarters inch machine cut thread. D and R were used for the die and rolled threads respectively. From the tabulated data it will be noticed that the one half inch die cut specimens begin with the number 4-1/2-D. This is because the first three specimens were discarded on account of the inaccuracy of the root diameter measurements. The anvils of the micrometer did not fit the V shaped thread. Thereafter an ordinary clamp caliper was used.

Nearly all the tests were made in a Riehle testing machine, having a capacity of 100000 pounds. The tests were run at slow speed until the yield point was passed and then higher speed used till rupture occurred. A little trouble was encountered with the eighteen inch rolled specimens. The head of the machine was so thick that not enough material was left to allow for attaching the instruments. A head made of two and one quarter inch slabs of steel was fitted to a 100000 pound Philadelphia testing machine and this machine used for the tests of short bolts.

Two extensometers were used to get the extensions. They were of the wire-wound drum type, reading to ten-thousandths of an inch. The other instruments used were micrometer calipers for the shank of the bolt, thread calipers reading accurately up to one- hundredth of an inch, and some tools such as wrenches and hammers for marking test pieces.

It was intended to get the elongation in the thread by the use of the two extensometers. One was to record the elongation in the known length of the shank and the other, the elongation in the part of the thread in tension and a part of the shank. Then knowing the elongation in inches per inch from the first extensometer and the length of the shank above the second extensometer, the elongation in the thread could be calculated by subtracting the elongation in the shank from the total elongation as recorded by the second extensometer. This was very good in theory but the length of the thread in tension was so indefinite that results as much as twenty five per cent too great or too small were possible since a part of the stress was in the nut as was plainly evidenced on examination.

A description of the actual carrying out of a tension test will not be amiss here. The specimen was placed in the machine without the instruments and the space inside of which the recording apparatus was to be placed, was marked roughly with a piece of chalk. The root and thread diameters were measured and recorded. The stock or shank extensometer was set up in the jig which takes the length of stock of eight inches, and the bolt clamped in. Then the second or thread extensometer was put on in the middle of the first with an ordinary clamp. The test piece was then set in the machine and the nut turned on. A nickle steel washer was used between the head of the machine and the nut. This plate had two small holes drilled to permit passing a small wire over a lever fastened to the nut, for the operation of the thread extensometer. The lever and its attachments are shown in Fig. I. The lower extensometer marked I is the shank extensometer and the upper marked II is the thread extensometer. The length of shank from No. II up to the threads was measured and the lower head of the machine raised. The jaws were placed as high up as possible because of the threads on the lower end of the test piece. The bar was then aligned and a light load of about a hundred pounds put on it. The pointers were placed at zero and the test was begun, first by putting on about 1200 pounds, but after that, readings were taken at equal increments of elongation on the thread extensometer as far as the elastic limit. Readings of both extensometers and load were obtained, and after every third reading the strain was relieved when the extensometer release readings were taken. The instruments were taken off after the elastic limit had been passed, and the load increased till rupture occurred.

In the shear tests no instruments were used because there did not seem to be any yield in the specimen, but a sudden failure. The thread diameter at the root and the length of the thread in shear were measured. The test was made on the end which had been previously prepared. The nut A, shown in figure II, was turned on till the threads to be sheared were well up in the nut. The exact position was varied in the different specimens. The bolt was then placed in the machine. The plate B acted as a washer and a head as in the tension test. The specimen was then aligned and the jaws C clamped on. The bolt was then loaded at slow speed while the poise was carefully adjusted so that any sign of yield could be noticed in the fall of the beam.

After the tension and shear tests had been pulled off, the ultimate strength of the bar was found except in the case of the rolled stock, where the bar ruptured in the tension test. For these it was necessary to drill a part of the material out of the thread and then set up the specimen as in the other ultimate tests. The part drilled out was as near the center as could be obtained with an ordinary center punch and drills.

***************DATA*****************

The data as compiled in Table I show the calculated results for each specimen, and the averages for each classification. The blank spaces in the plate are where no definite values could be obtained from the curves. With a different selection of points on the curve this would probably not occur. There was some difficulty in getting the ultimate strength of the rolled threads as has been mentioned before and explained, but in the table the figures give the stress on the whole area of the root of the thread as calculated from the reduced part under test. The results obtained are probably not widely different from what they would be if fracture had occurred across the original area. The calculated results were used in finding the per cent strength for these threads which, in every case, was greater than one hundred per cent.

The point of rupture in the machine and die cut threads was about half way between the nut and the shank. This was not true of the rolled. They broke at the bottom of the drilled out portion. The rolled specimens were hard to handle in the ultimate tests on the threads on account of the difficulty of setting them up straight. In one case there was evidence of a little bending action. This may have been due partially to the poor bearing surface of the nut. This fact entered into the results of some of the other tests and was unavoidable.

The comparative strength of the root and shank of the thread is shown in Table II. Reducing the load on the shank and on the thread, at the different events, to pounds per square inch shows that the stress on the smaller area is greater than that on the larger area of the shank. This seems to be an accepted fact for static tension tests. The difference in the stress on the area at the root of the thread and that on the shank is greatest for the rolled threads, the machine cut next, and the die cut least. From this, it seems that the lathe tool has something of the effect on the material that rolling has. The table also shows that in the case of the rolled bolts the per cent strength is greatest at the ultimate, while for the die- and machine-cut, the yield point shows the greatest per cent strength.

The shear tests brought out some important considerations in the design of nuts, including lock nuts. There is a minimum allowable thickness which may be sufficient to stand the strain on the bolt. If we assume a factor of safety of five under static loads, the following formula is derived:-

$$\text{Thickness of nut} = \frac{T}{S \cdot C}$$

where T is the allowable stress in pounds on the bolt in tension, S, the allowable shearing stress in pounds per square inch, and C, the circumference of the root of the thread in inches. The nut must fit well in each case in order that this may hold good. Table No. III shows the thickness of the nut required to stand the strain of the threaded portion, except in the case of the rolled threads, where the threaded portion was stronger than the shank.

The efficiency of a bolt has been taken to mean the ratio of the load on the thread to the load on the shank of the bolt at the corresponding events. For instance the efficiency of a bolt at the yield point would be the ratio of the load on the thread at yield, determined from the curve, to that of the shank determined in a similar manner. It is concluded that the events on the stress-strain curves for the shank and thread are for the thread alone since the area of that section is smaller and any failure would appear in the threaded portion first. This is not exactly true of the rolled threads, but it has been assumed that the events on this curve were also true for the threaded part. The efficiency has been determined for each kind of thread at the elastic limit, yield point, and ultimate. Plate I gives the results of these calculations and shows that the relative per cent strengths of the rolled threads at ultimate, is much greater than the two others. The same is true of the other events. The efficiency of the one inch rolled was one hundred nineteen (119) per cent at the ultimate, while the die-and machine-cut were eighty three (83) and eighty four (84) per cent respectively. The per cent strength seems to increase with the diameter of the shank for the die and machine cut threads. This was the case in all but the machine-cut threads at yield, where it decreased slightly. In the rolled threads the one inch increased a little at the ultimate, but, for all other events on the different sizes, the curves ran about horizontal. These curves from plate I show that the rolled threads are by far stronger than the others, and that there is no choice as far as strength is concerned between the die and machine threads. The working of the metal increases the strength and this no doubt accounts for the high values in favor of the rolled threads.

Plates No. III---XXXI are the load-elongation curves for each specimen that was tested. Each curve was plotted on a separate sheet to avoid confusion, and for the reason that the curves could not be reduced to the same basis since the areas and the lengths of the threads were not uniform. The latter could not be accurately determined. The ordinates were load in pounds and not in pounds per square inch, because the ratio of the loads was wanted at the events, and by plotting the curves as they are the load can be read directly. The elongations were plotted as they were read. The points of release were plotted and show definitely where permanent set began.

Johnson's method was used in determining the elastic limit, in preference to the old way of assuming the elastic limit at the point where the curve broke away from the tangent. His method is as follows; take one half of the abscissa of any point on the straight line below the elastic limit and lay it off to the right from the chosen point on the curve. A line drawn through this point to the intersection of the given straight line with the vertical through O determines the position of a second line parallel with the construction line and tangent to the curve. The point of tangency gives the elastic limit. This is shown better on Plate III where AB represents the length from the point to the ordinate, and BC, one half of this distance laid off to the right. CO is the line through the origin and this last determined point, and EF is the line parallel to OB tangent to the curve at the point G,- the elastic limit.

The yield point was taken at the point of inflection on the curve after the elastic limit had been passed. This is not a very accurate way to determine this point, but knowing that in tension tests of soft steel the curve is horizontal at what is called the yield, this method is considered sufficiently accurate for these tests. The ultimate was simply the maximum load on the specimen.

Plate II shows the ratio of areas at the root of the thread and the shank of the bolt for the three kinds of bolts. The curves show that the ratio for the die-and machine-cut bolts are practically the same, but the rolled threads are from nine hundredths to twelve hundredths nearer unity. The fact that the rolled thread is not sharp but of rounding section probably accounts for this high ratio. The fact that the curves for the rolled threads decrease, and the die-and machine-cut increase cannot be taken as of any consequence. The curves if carried farther would probably become horizontal.

********** CONCLUSIONS *********

From the results obtained in this thesis the following conclusions are drawn in regard to the kind of thread and their respective strengths:-

(1) The ratio of the area of cross section at the root of the thread to the area of the shank is practically a constant for the rolled threads and increases slightly for the die-and machine-cut threads as the size of the bolt increases.

(2) The efficiency of the rolled thread in tension is greatest at the ultimate, and is also greater than the machine or die cut threads at any event. This efficiency decreases as the size of the bolt increases. The efficiency of the machine and die cut threads is practically the same, and increases as the size of the bolt increases.

(3) The die-and machine-cut threads will stand a greater load in shear on the threads than the specimens of rolled stock because of the loose fit of the nuts furnished with this stock. The rolled bolts are not adapted to the uses that machine bolts are put to, or to any work where a close fit of the shank is required.

(4) A thickness of nut of one half the diameter of the

stock is all that is necessary to prevent shearing in the nut for the die-and machine-cut threads while for the rolled threads a thickness of three-fourths of the stock is required.

SAMPLE DATA SHEET.

SPECIMEN 3 - 1 - D.

Load in lbs.	Total elong-ation in in.	Elong-ation in 8 in. of bar in in.	At release to 500 lbs. Extensometer No. I	No. II	Remarks	
1600	.0051	.0008			Diameter at root	.84"
4100	.0111	.0016			Diameter of stock	1.0
8800	.0154	.0030	.0119	.0004	Diameter of stock	
11200	.0205	.0041			after rupture	.961
16100	.o255	.0059			Diameter at root	
20600	.0302	.0075	.0198	.0004	after rupture	.69
24200	.0391	.0082			Length from Ext. No. I	
24900	.0495	.0082			up to end of thread	9.2
24900	.0560	.0088	.0440	.0004	Nut fit snug.	
25200	.0630	.0089				
25800	.0685	.0090				
26200	.0745	.0092	.0610	.0004		
26800	.0810	.0093				
27400	.0870	.0098				
27700	.0950	.0122	.0812	.0035	Scaled slightly at bottom.	
28100	.1034	.0208				
27900	.1095	.0358				
27700	.1165	.0541	.1018	.0448		
28000	.1308	.0861				
28100	.1465	.1120				
28000	.1655	.1145	.1512	.1042		
28100	.1855	.1339				
28200	.2100	.1625				
29200	.2605	.1321	.2500	.1695		
29200	.2830	.1842				
30100	.3070	.1882			Scaled all over.	
31300	.3438	.2380	.3245	.2042		
38400	Ultimate of thread.					
35000	Rupture.					

SPECIMEN 3 - 1 - D.
In Shear.

16500 Ultimate	Length in shear .2"
Rupture not definite as failure was gradual.	Diameter at root .84
Sheared nut and bolt.	Diameter of stock 1.0
Good clean shear.	Nut fit snug
	Threads near middle of nut.

TABLE I

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Item	Specimen No.	Diameter of shank in in.	Diam at root of thread in in.	Area of cross section in sq in.		Ratio of areas of root to shank	Elastic limit in pounds		Yield point in pounds in the		Ultimate in pounds in the		Elastic limit in pounds per sq. inch in the		Yield point in pounds per sq inch in the		Ultimate in pounds per sq inch in the		Ratio of load on the thread to load on shank			Ultimate load in shear in lbs	Area in shear sq in	Ultimate load in shear lbs per sq in
				shank of bolt.	at root of thread		in the shank	in the thread	shank	thread	shank	thread	shank	thread	shank	thread	shank	thread	at Elastic limit	at Yield point	at Ultimate			
1	4-½-D	.495	.400	.1924	.1256	.6525	6850	5300	7800	—	12900	10470	35550	42250	40500	—	67100	83300	.7740	—	.8110	9650	.3755	35430
2	5-½-D	.496	.410	.1930	.1320	.6840	7080	5180	7100	5900	10900	8400	36700	39250	36730	44600	56400	63600	.7320	.8310	.7710	6130	.2123	28900
3	6-½-D	.505	.410	.2002	.1320	.6590	6750	4250	6900	5700	10900	8000	33700	32180	34450	43200	54400	60600	.6300	.8260	.7340	7240	.2575	28100
4	7-½-D	.494	.410	.1916	.1320	.6885	—	5200	—	6000	12900	10250	—	39380	—	45400	67400	77600	—	—	.7940	6400	.2261	28300
5	8-½-D	.503	.400	.1986	.1256	.6320	6950	4150	7100	5600	10900	8000	35000	33050	35700	44600	54900	63700	.5970	.7890	.7340	6500	.2060	31540
6	9-½-D	.504	.410	.1994	.1320	.6620	6400	4450	6800	6000	10900	8000	32100	33700	34080	45400	54650	60600	.6960	.8830	.7340	5650	.2060	27400
7	10-½-D	.500	.410	.1964	.1320	.6720	7280	5300	7700	6200	12900	10200	37050	40200	39200	46900	65650	77250	.7280	.8050	.7910	6200	.2512	24680
8	AVERAGE	.4996	.4071	.1959	.1302	.6641						9040	35020	37140	36780	45020	60100	69500	.6928	.8268	.7670			29200
9	1-½-R	.446	.410	.1562	.1320	.8450	6800	5480	6920	6880	9400	8000*	43500	41500	44300	52100	60200	79300*	.8050	.9940	1.1210#	5340	.2190	24380
10	2-½-R	.444	.410	.1550	.1320	.8520	6200	5900	6700	6700	9440	7900*	39950	44700	43150	50700	60850	78300*	.9515	1.000	1.095#	4840	.1884	25700
11	3-½-R	.450	.400	.1591	.1256	.7885	5800	6600	6900	6900	9500	8100*	36450	52600	43350	54900	59700	85700*	1.1380	1.000	1.132#	4480	.1932	23200
12	AVERAGE	.4467	.4067	.1568	.1299	.8285					9450		39970	46270	43600	52570	60250	81100	.9648	.9980	1.1160			24430
13	1-¾-D	.742	.620	.4322	.3016	.6980	—	9100	—	11000	21100	16800	—	30150	—	36500	48800	55700	—	—	.7970	11000	.4088	26900
14	2-¾-D	.745	.620	.4357	.3018	.6925	12400	9650	13100	10700	20800	16300	28500	32000	30100	35450	47750	54000	.7780	.8170	.7840	12000	.4283	28020
15	3-¾-D	.745	.620	.4357	.3018	.6925	—	9900	—	10780	21100	14800	—	32780	—	35700	48400	49100	—	—	.7020	10100	.3894	25920
16	4-¾-D	.748	.620	.4392	.3057	.6960	13300	9500	13720	10900	20800	16700	30300	31100	31230	35700	47400	54600	.7140	.7940	.8030	12500	.4478	27930
17	5-¾-D	.740	.620	.4299	.3018	.6820	11100	8580	12500	10700	20600	16260	25830	28430	29100	35450	47900	53850	.7730	.8560	.7890	13500	.3894	34700
18	AVERAGE	.7440	.620	.4345	.3025	.6922						16170	28210	30890	30140	35760	48050	53460	.7550	.8223	.7750			28690
19	1-¾-M	.750	.620	.4416	.3018	.6830	12900	9600	13350	12000	24350	20000	29230	31800	30200	39770	55100	66300	.7440	.8990	.8225	11700	.4478	26130
20	2-¾-M	.747	.620	.4380	.3018	.6885	12700	9550	12800	9750	20800	17200	29000	31630	29200	32300	47400	57000	.75150	.7610	.8270	10800	.4283	25250
21	3-¾-M	.751	.620	.4428	.3018	.6975	12200	9200	13200	11500	24500	19600	27550	30450	29810	38100	55350	65000	.7540	.8720	.8000	9600	.3831	25050
22	AVERAGE	.7493	.620	.4408	.3018	.6897						18930	28590	31290	29740	36720	52610	62770	.7498	.8440	.8165			25480
23	1-¾-R	.692	.630	.3759	.3116	.8285	14350	14250	14500	14450	23400	19730*	38150	45700	38550	46400	62300	83900*	.9940	.9960	1.1180#	8040	.3215	24980
24	2-¾-R	.707	.630	.3924	.3116	.7940	14400	11700	14500	14450	23600	18710*	36700	37550	36950	46400	60150	79700*	.8120	.9960	1.053#	8600	.4946	17400
25	3-¾-R	.702	.630	.3869	.3116	.8060	14200	14080	14520	14480	23700	18660*	36700	45200	37500	46500	61250	79400*	.9920	.9970	1.045#	9600	.4946	19380
26	AVERAGE	.7003	.630	.3851	.3116	.8095					23570		37180	42820	37670	46430	61230	81000	.9327	.9963	1.072			20590
27	1-1-D	.988	.840	.7685	.5539	.7210	26600	21500	28200	24000	46900	38800	34630	38820	36700	43300	61100	70100	.8080	.8520	.8280	20000	.6067	33000
28	2-1-D	.990	.840	.7694	.5539	.7190	27000	21000	—	24300	46100	38500	35100	37920	—	43850	59850	69600	.7780	—	.8360	21300	.6594	32300
29	3-1-D	1.000	.840	.7850	.5539	.7060	26800	22500	28200	24900	45800	38400	34150	40600	35900	45000	58300	69400	.8395	.8825	.8390	16500	.5275	31280
30	AVERAGE	.9927	.840	.7743	.5539	.7153						38570	34630	39110	36300	44050	59750	69700	.8085	.8673	.8343			32190
31	1-1-M	.992	.840	.7725	.5539	.7170	24000	18800	25700	21250	39300	33300	31080	33950	33250	38380	50900	60150	.7830	.8270	.8390	18200	.7749	23500
32	2-1-M	.992	.840	.7725	.5539	.7170	26800	21400	28050	23000	45500	38000	34700	38680	36330	41600	58900	68600	.7990	.8200	.8340	20300	.7122	28520
33	3-1-M	.993	.840	.7741	.5539	.7150	27800	20200	28300	23600	45300	38200	35930	36500	36520	42600	58600	68900	.7270	.8340	.8440	20800	.6594	31550
34	AVERAGE	.9923	.840	.7730	.5539	.7163						36500	33900	36380	35370	40860	56130	65880	.7697	.8270	.8390			27860
35	1-1-R	.923	.830	.6670	.5420	.8125	22500	17400	23200	—	36400	34600*	33720	32100	34780	—	54600	80200*	.7730	—	1.1925#	16300	.6440	25300
36	2-1-R	.925	.830	.6720	.5420	.8060	23400	22100	23400	23200	36400	34600*	34820	40700	34828	34530	54200	80200*	.9440	.9920	1.1925#	20100	.6260	32100
37	3-1-R	.930	.830	.6780	.5420	.7990	23000	22000	23500	22700	36500	34140*	33950	40600	34630	41850	53800	79200*	.9570	.9670	1.1760#	13900	.6260	22220
38	AVERAGE	.9260	.830	.6723	.5420	.8058					36430		34160	37800	34750	38190	54200	79867	.8913	.9795	1.1870			26540

* These bars were drilled out to make this section weaker. Drill used on the 1 inch bar was ⅝; on the ¾ inch was $\frac{5}{16}$; on the ½ inch was .199.

This ratio = $\frac{\text{Column 19} \times \text{Column 6}}{\text{Column 12}}$

TABLE II

1/2 Inch Specimen.

	Rolled Stock in lbs. per sq. in. in shank	thread	Machined Stock in lbs. per sq. in. in shank	thread	Die Cut Stock in lbs. per sq. in. in shank	thread	Increase in percent strength in lbs. per sq. inch Rolled	Mach.	Die
El. Lim.	39970	46270			35020	37140	15.5		6.0
Y. Point	43600	52570			36780	45020	20.5		22.8
Ultimate	60250	81100			60100	69500	34.5		15.5

3/4 Inch Specimen.

El. Lim.	37180	42820	28590	31290	28210	30890	15.2	9.5	9.5
Y. Point	37670	46430	29740	36720	30140	35760	23.0	23.3	18.5
Ultimate	61230	81000	52610	62770	48050	53460	32.3	19.2	11.3

1 Inch Specimen.

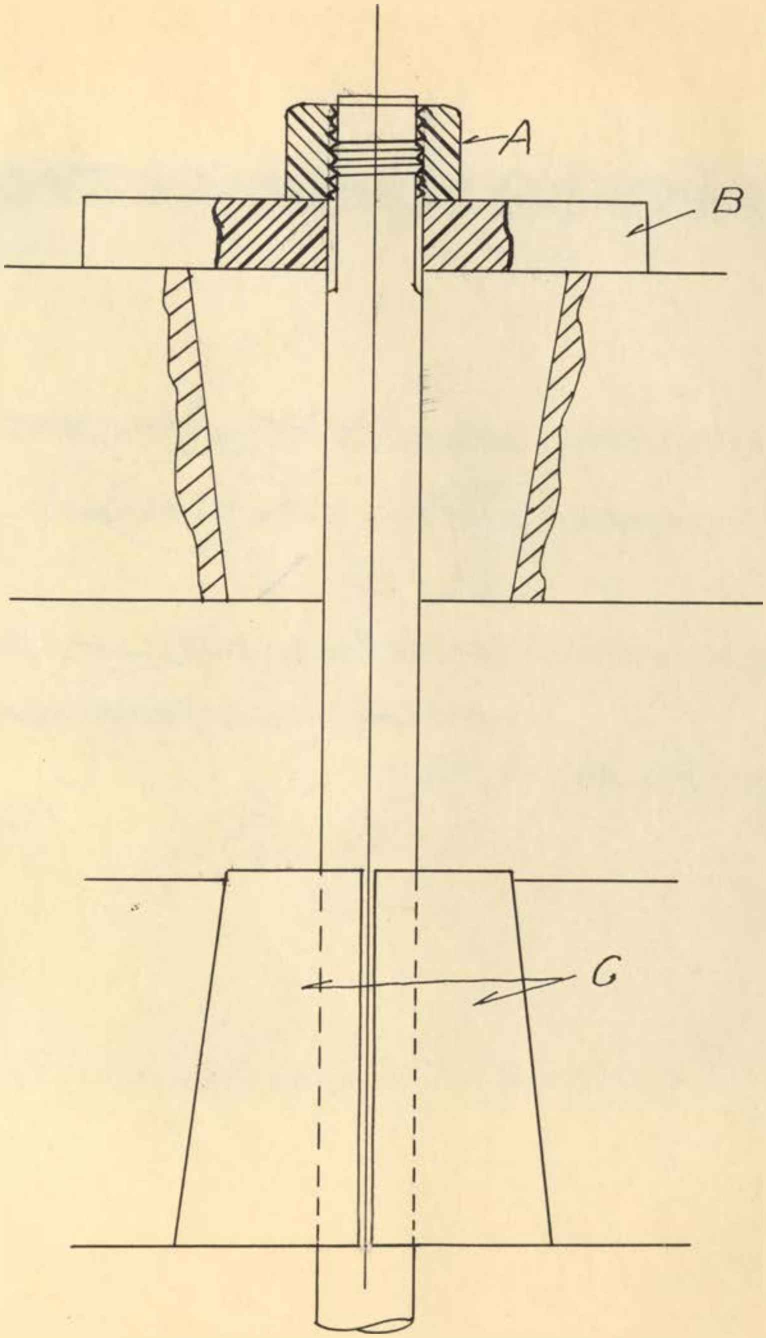
El. Lim.	34160	37800	33900	36380	34630	39110	10.8	7.2	12.8
Y. Point	34750	38190	35370	40860	36300	44050	9.8	15.5	21.3
Ultimate	54200	79867	56130	65880	59150	69700	47.2	17.5	17.8

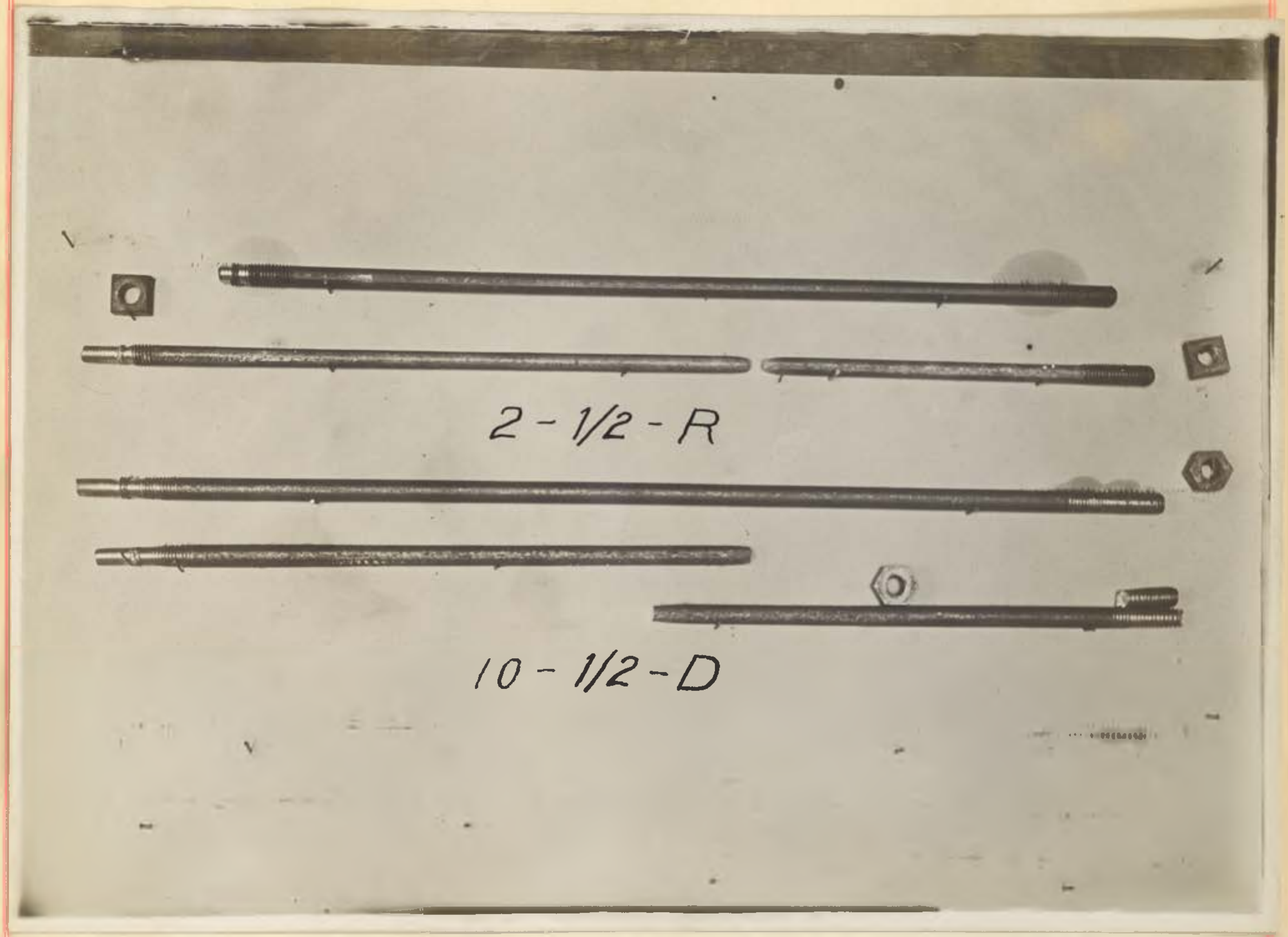
Table III

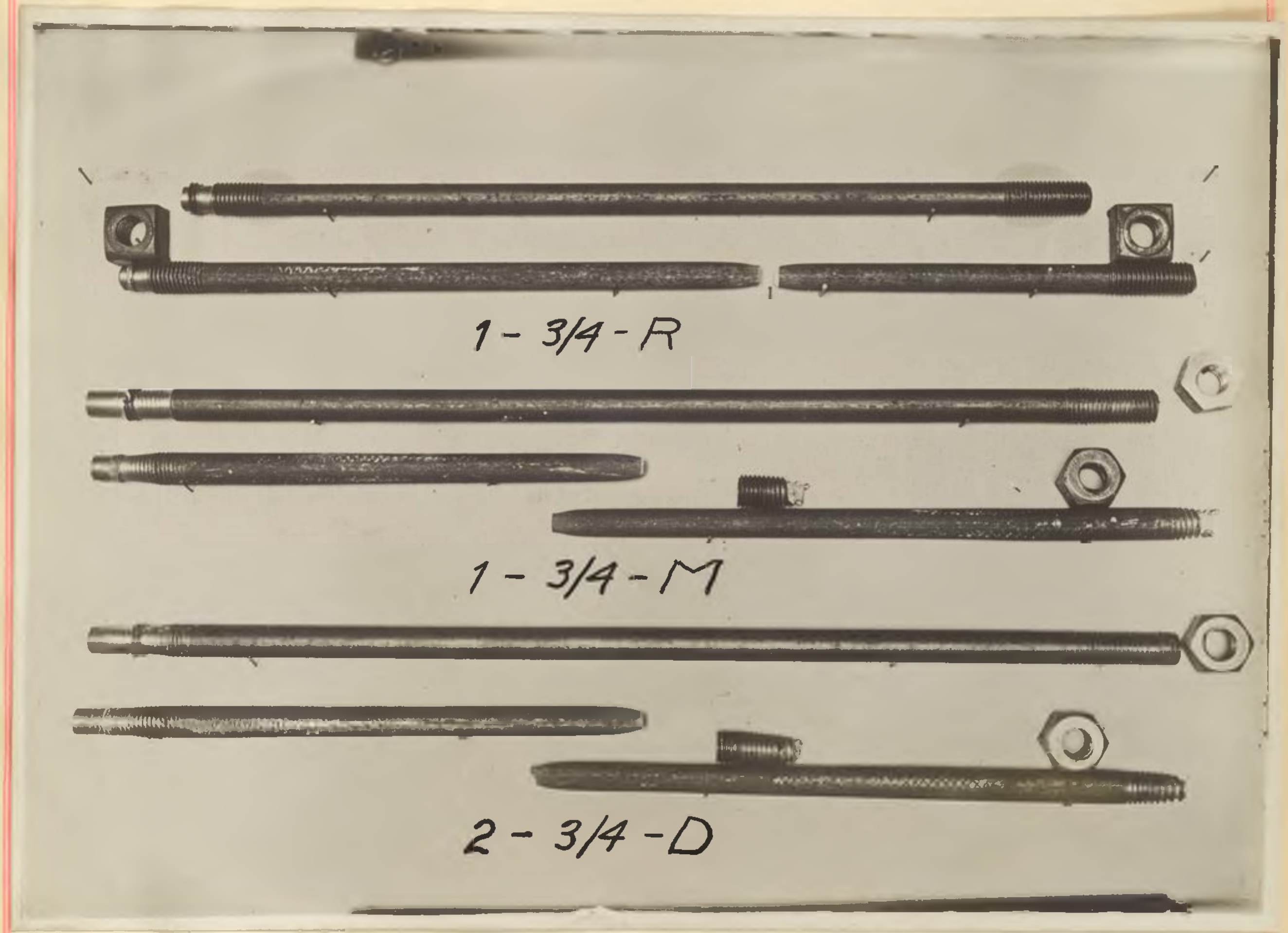
Specimen	Actual stress on bolt in pounds	Diameter of root of thread in inches	Circumference of root, inches	Allowable shear in lbs. per sq. inch.	Thickness of nut in inches.
1/2" D	9040	0.4071	1.281	5840	0.241
1/2" R	9450	0.4067	1.279	4890	0.302
3/4" D	16170	0.62	1.949	5740	0.289
3/4" M	18930	0.62	1.949	5100	0.381
3/4" R	23570	0.63	1.98	4120	0.576
1" D	38570	0.84	2.64	6440	0.454
1" M	36500	0.84	2.64	5570	0.497
1" R	36430	0.83	2.609	5300	0.531

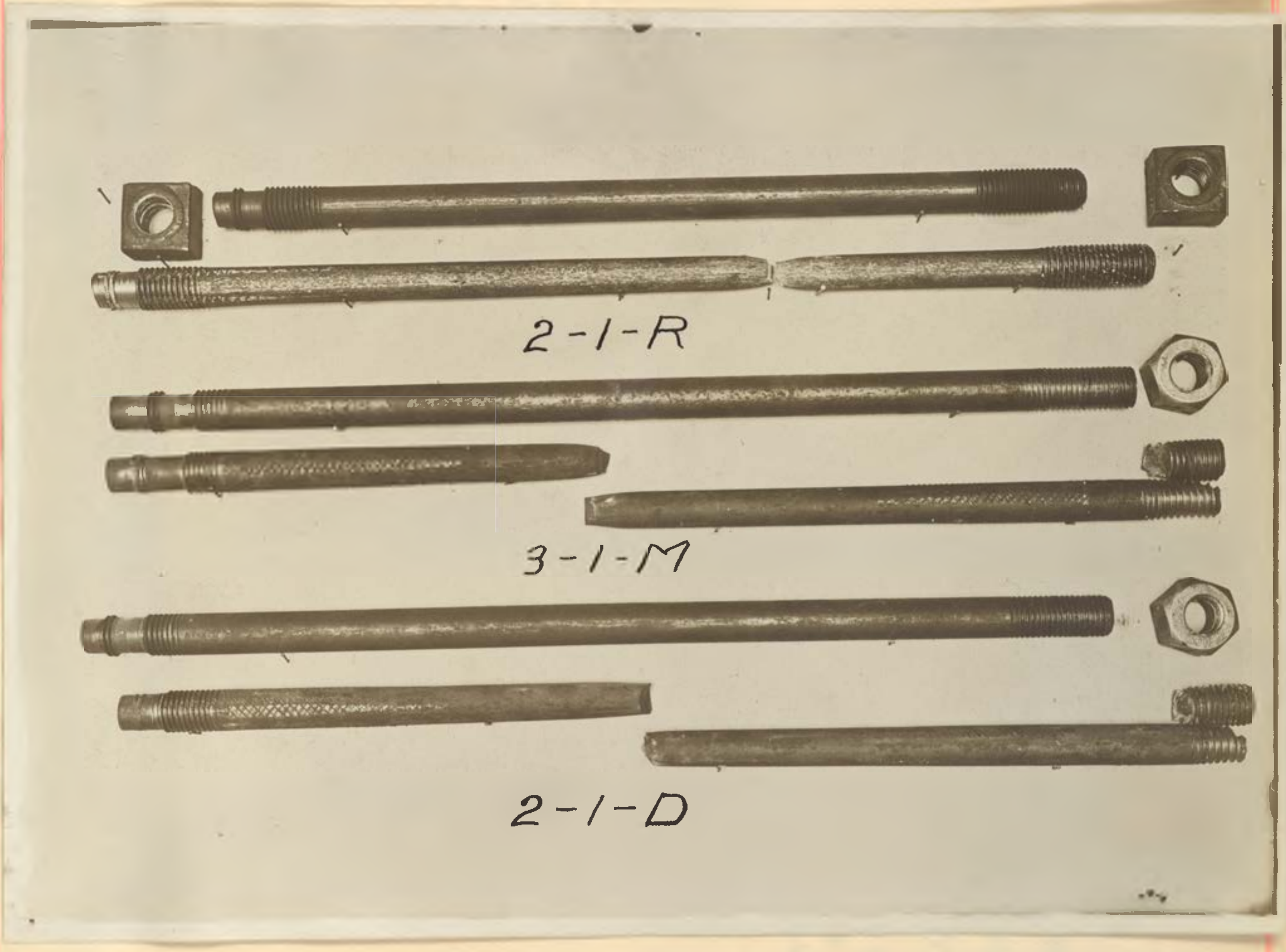
Fig. I

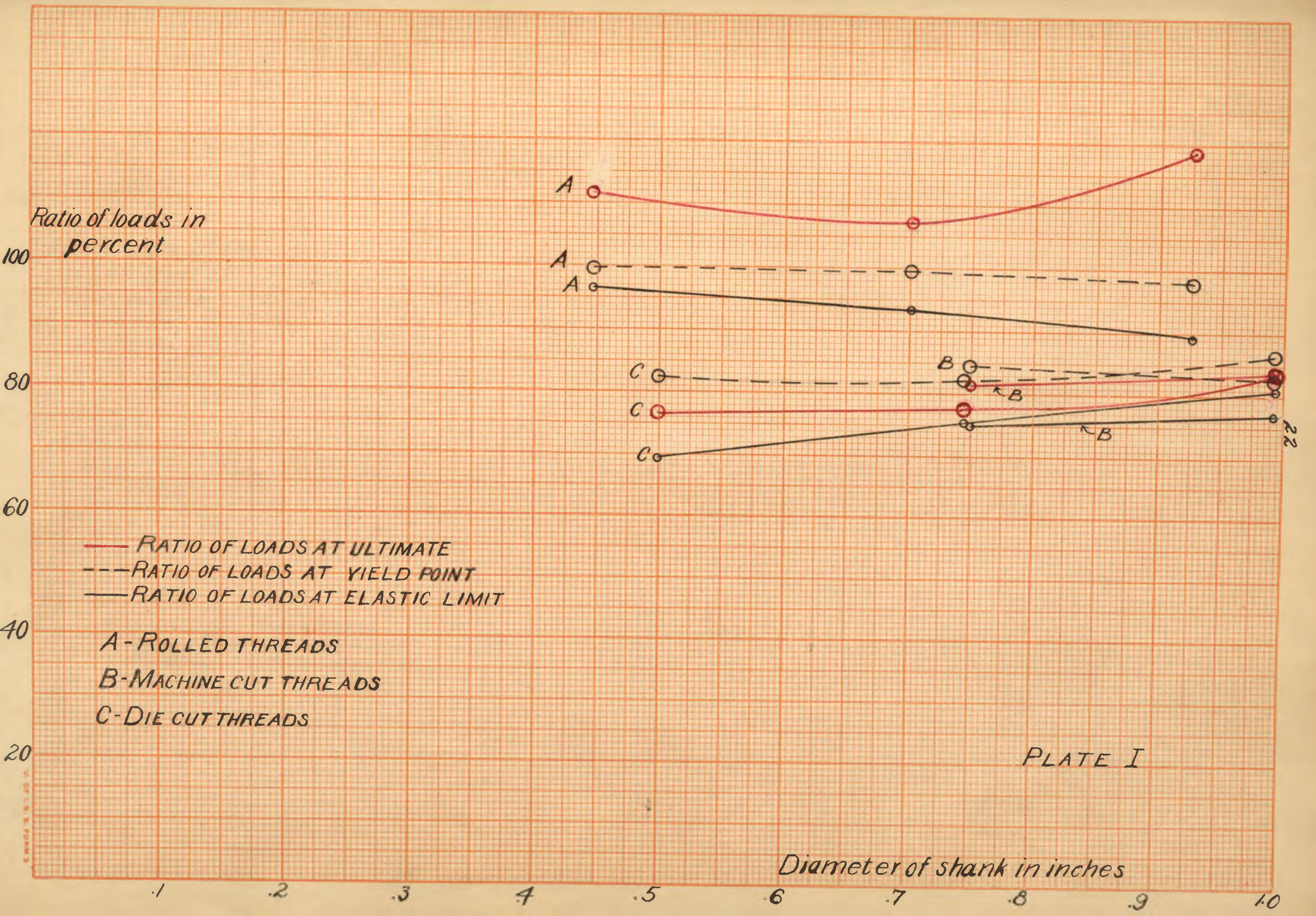
Fig II




2 - 1/2 - R
10 - 1/2 - D

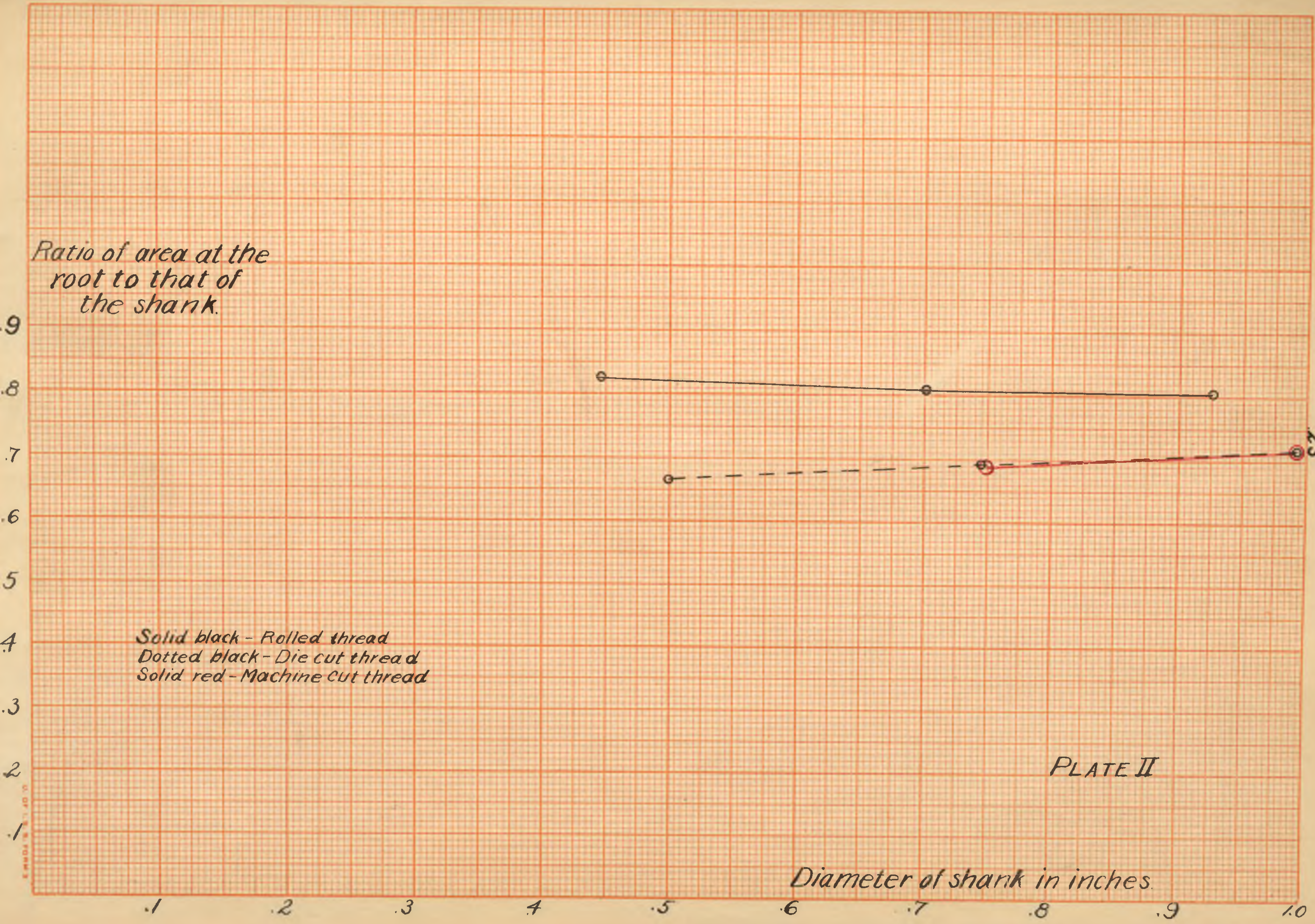

1 - 3/4 - R
1 - 3/4 - M
2 - 3/4 - D


2-1-R
3-1-M
2-1-D

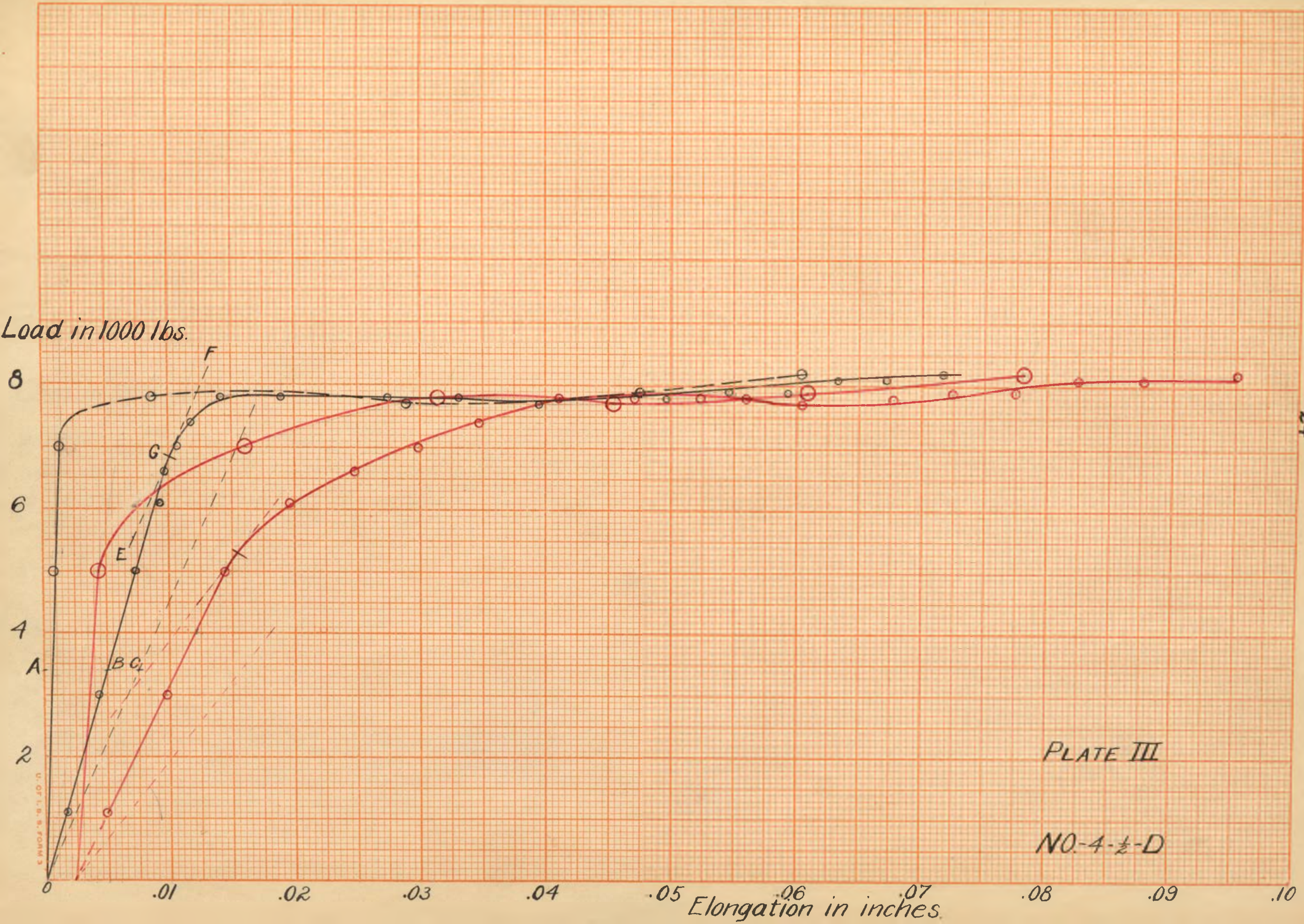


Ratio of loads in percent
100
80
60
40
20
A
A
A
B
C
C
C
B
B
22
RATIO OF LOADS AT ULTIMATE
RATIO OF LOADS AT YIELD POINT
RATIO OF LOADS AT ELASTIC LIMIT
A-ROLLED THREADS
B-MACHINE CUT THREADS
C-DIE CUT THREADS
Diameter of shank in inches
.1
.2
.3
.4
.5
.6
.7
.8
.9
1.0

PLATE I

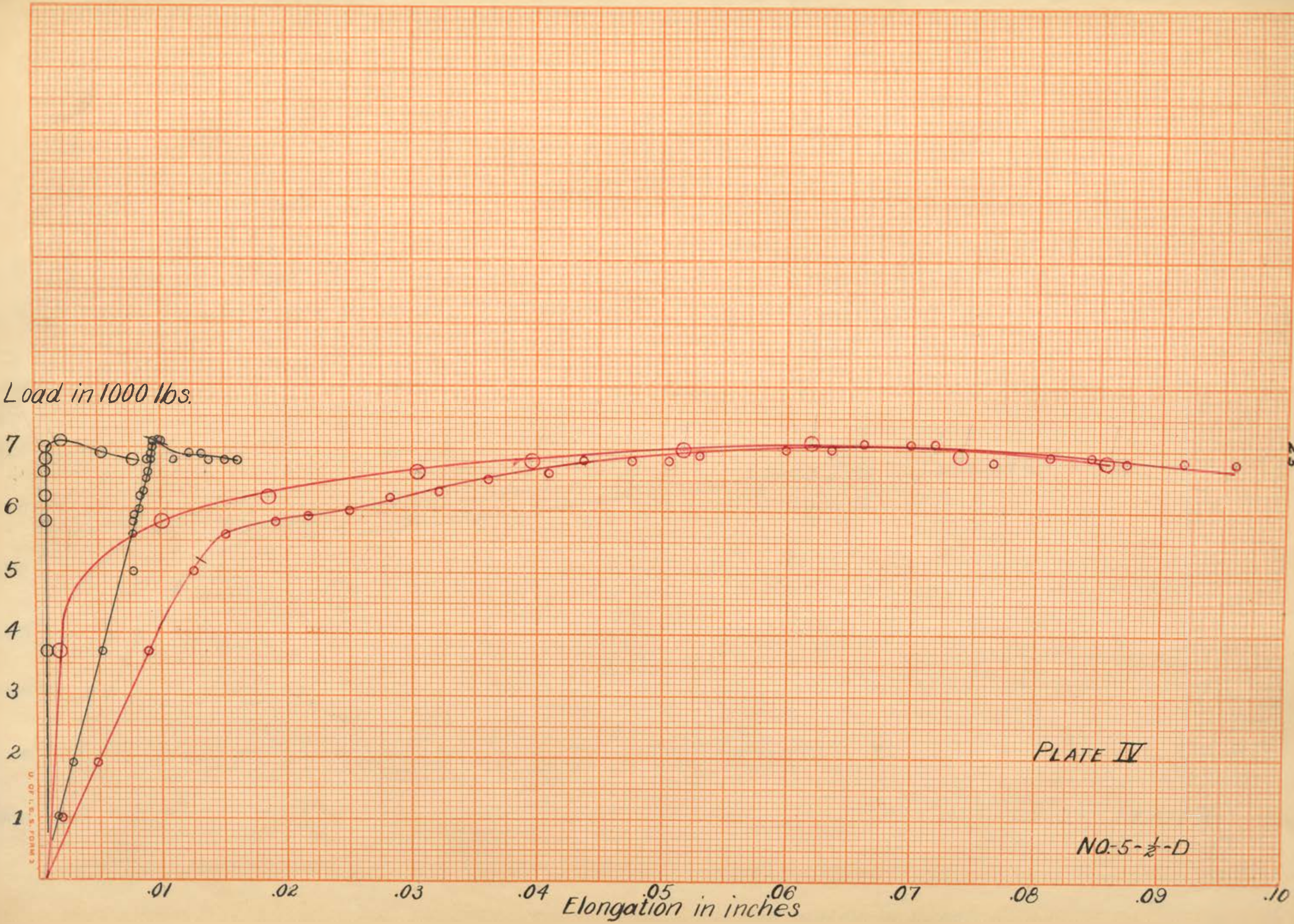


Ratio of area at the root to that of the shank.
.9
.8
.7
.6
5
.4
.3
.2
.1
Solid black - Rolled thread
Dotted black - Die cut thread
Solid red - Machine cut thread
23
PLATE II
Diameter of shank in inches.
.1
.2
.3
.4
.5
.6
.7
.8
.9
1.0



Load in 1000 lbs.
8
6
4
2
0
A
B
C
E
F
G
.01
.02
.03
.04
.05
.06
.07
.08
.09
.10
Elongation in inches.
PLATE III
NO-4-½-D

24


Load in 1000 lbs.
7
6
5
4
3
2
1
.01
.02
.03
.04
.05
.06
.07
.08
.09
.10
Elongation in inches
25
PLATE IV
NO-5-½-D

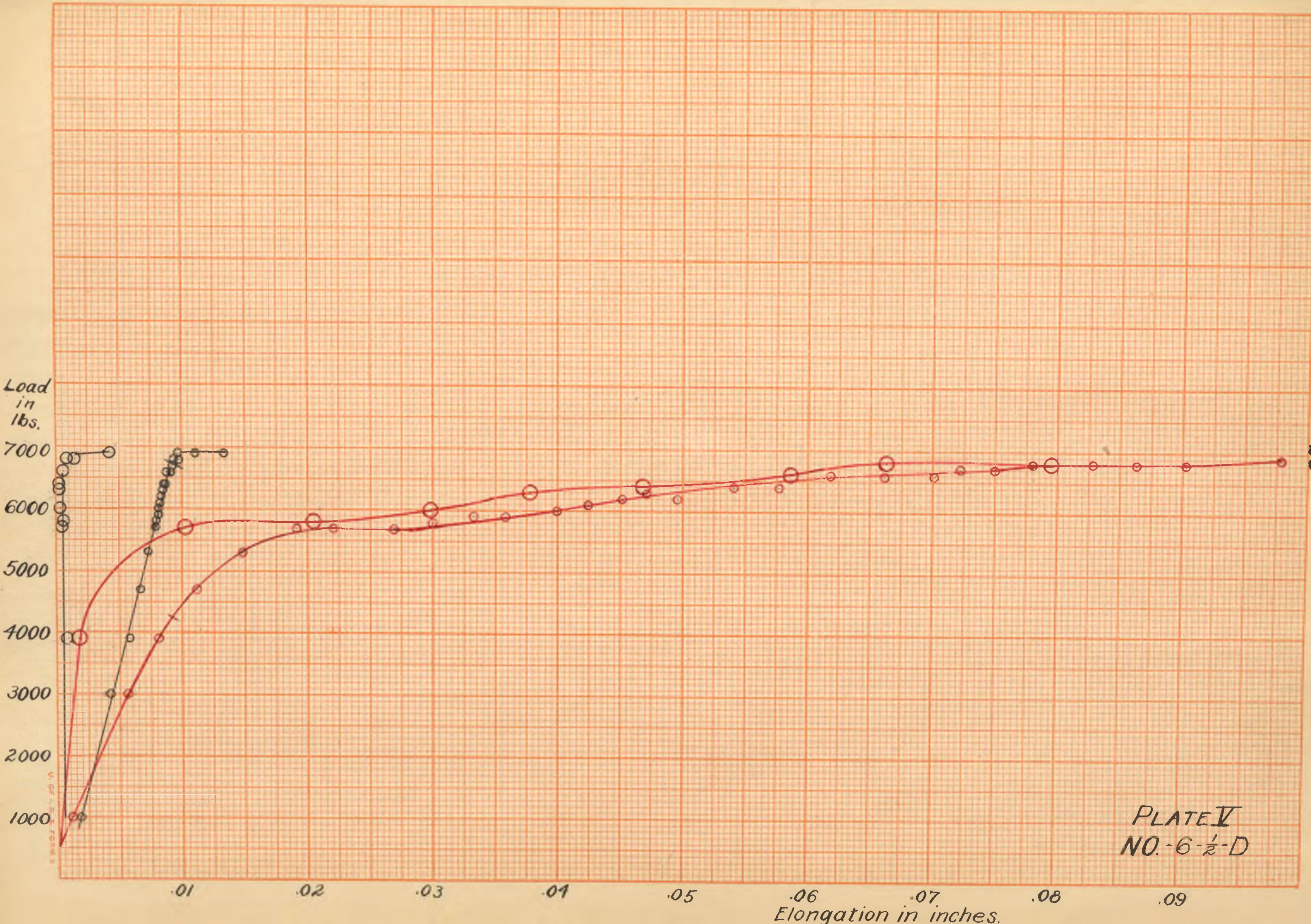
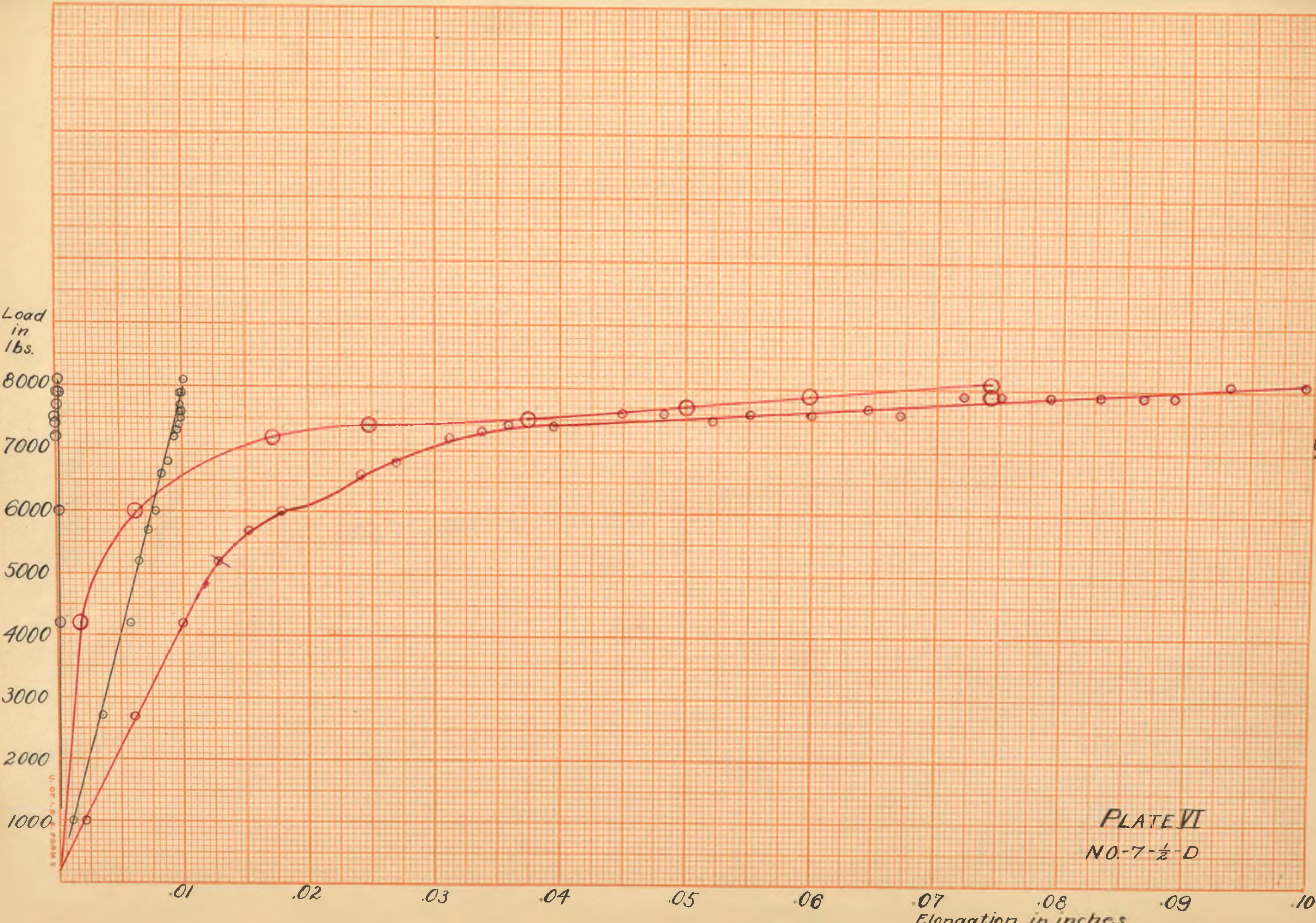


PLATE V
NO.-6-½-D


Load in lbs.
8000
7000
6000
5000
4000
3000
2000
1000
.01
.02
.03
.04
.05
.06
.07
.08
.09
.10
Elongation in inches.
PLATE VI
NO.-7-½-D

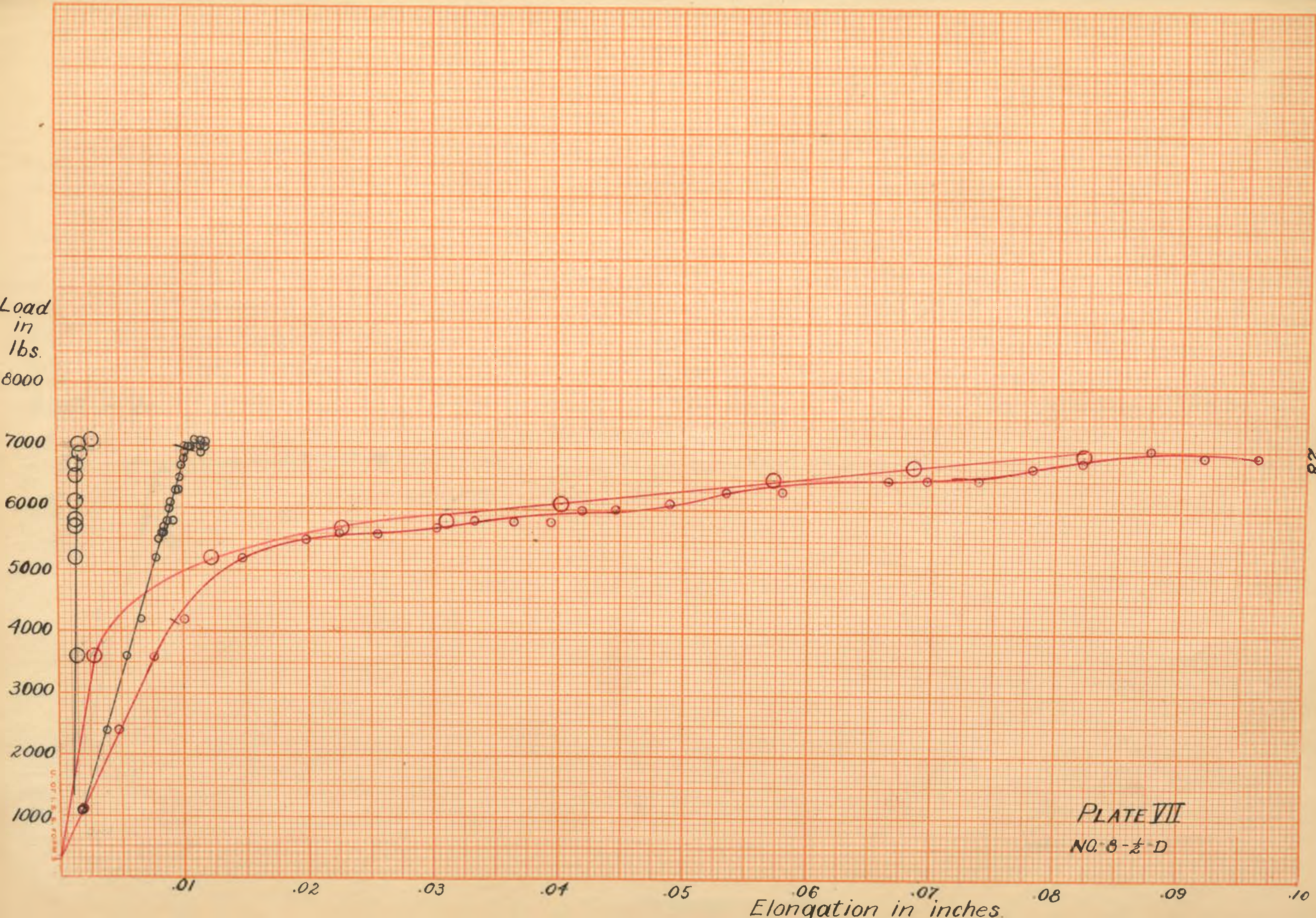
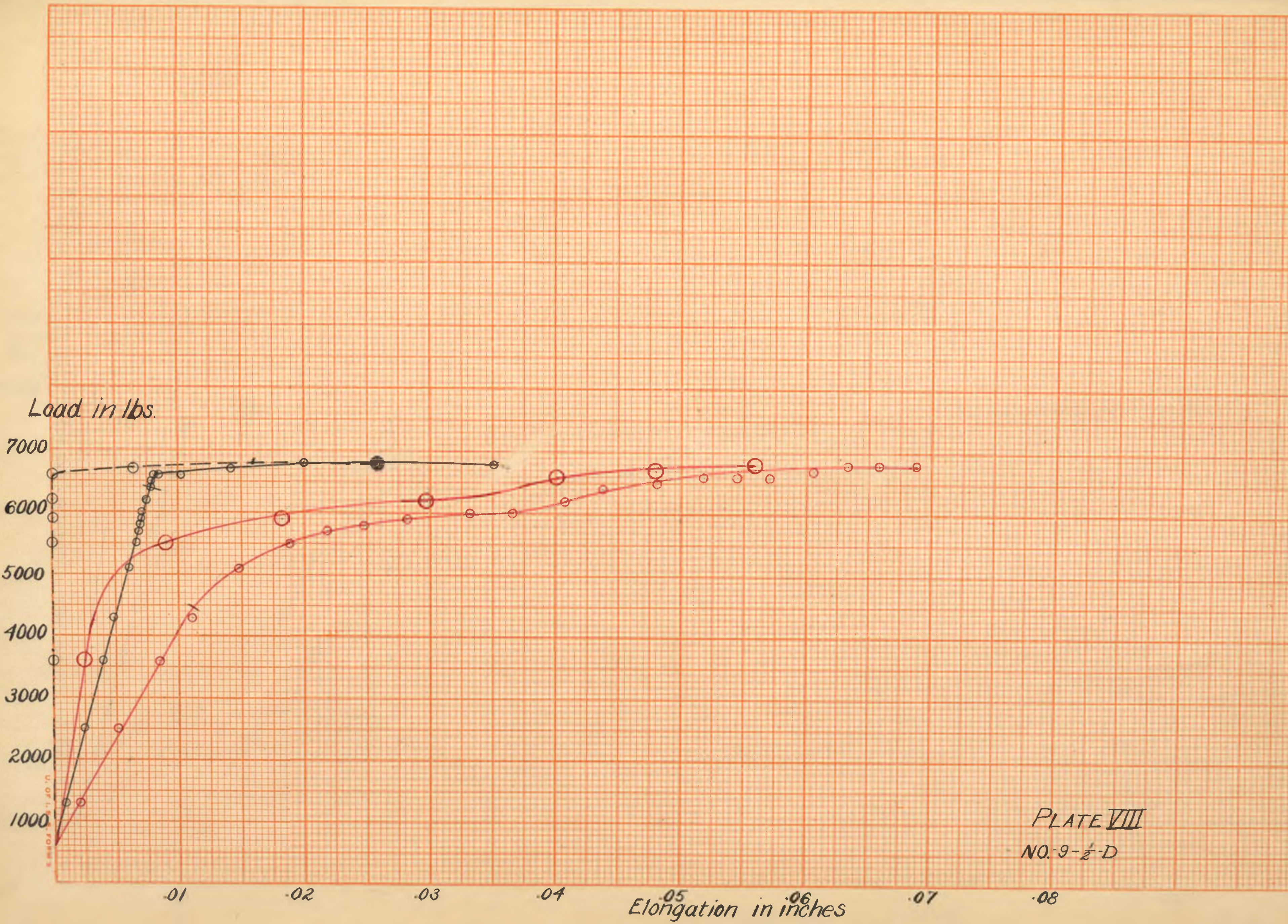
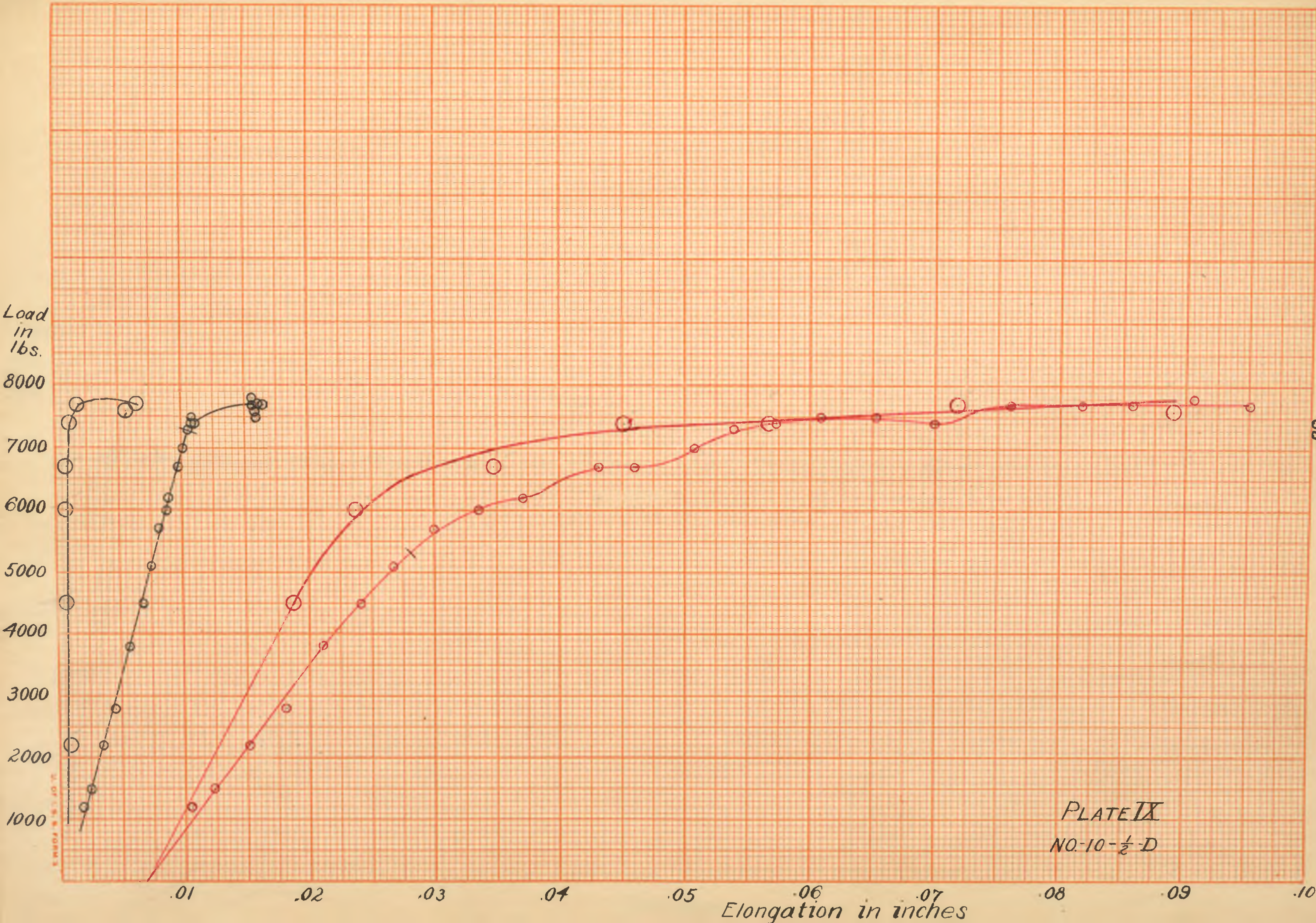


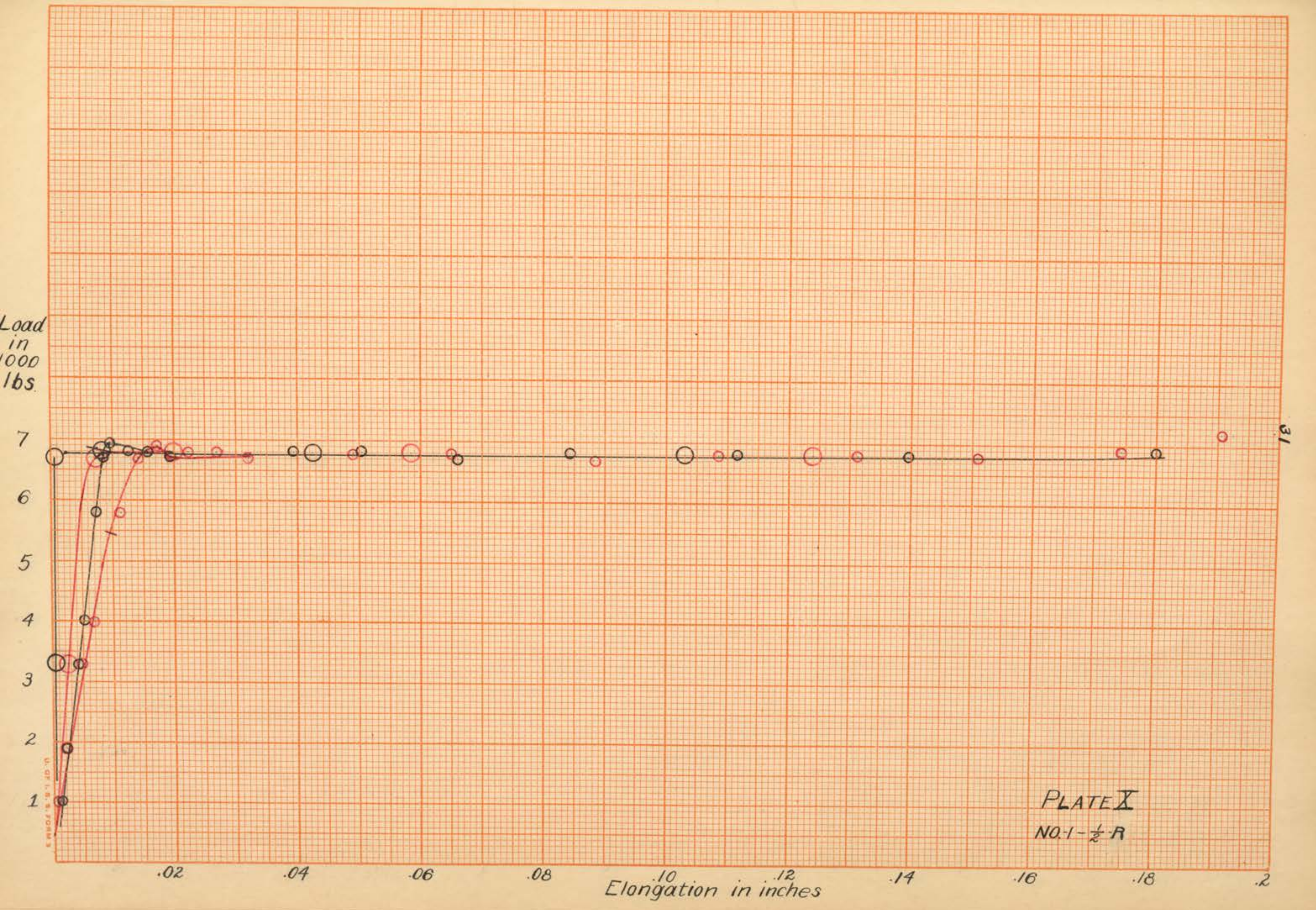
PLATE VII

NO. 8-½ D


Load in lbs.
7000
6000
5000
4000
3000
2000
1000
.01
.02
.03
.04
.05
.06
.07
.08
Elongation in inches
PLATE VIII
NO. 9-½-D



Load in lbs.
8000
7000
6000
5000
4000
3000
2000
1000
.01
.02
.03
.04
.05
.06
.07
.08
.09
.10
Elongation in inches
PLATE IX
NO.10-½-D



Load in 1000 lbs.
7
6
5
4
3
2
1
.02
.04
.06
.08
.10
.12
.14
.16
.18
.2
Elongation in inches
PLATE X
NO. 1 - ½ R

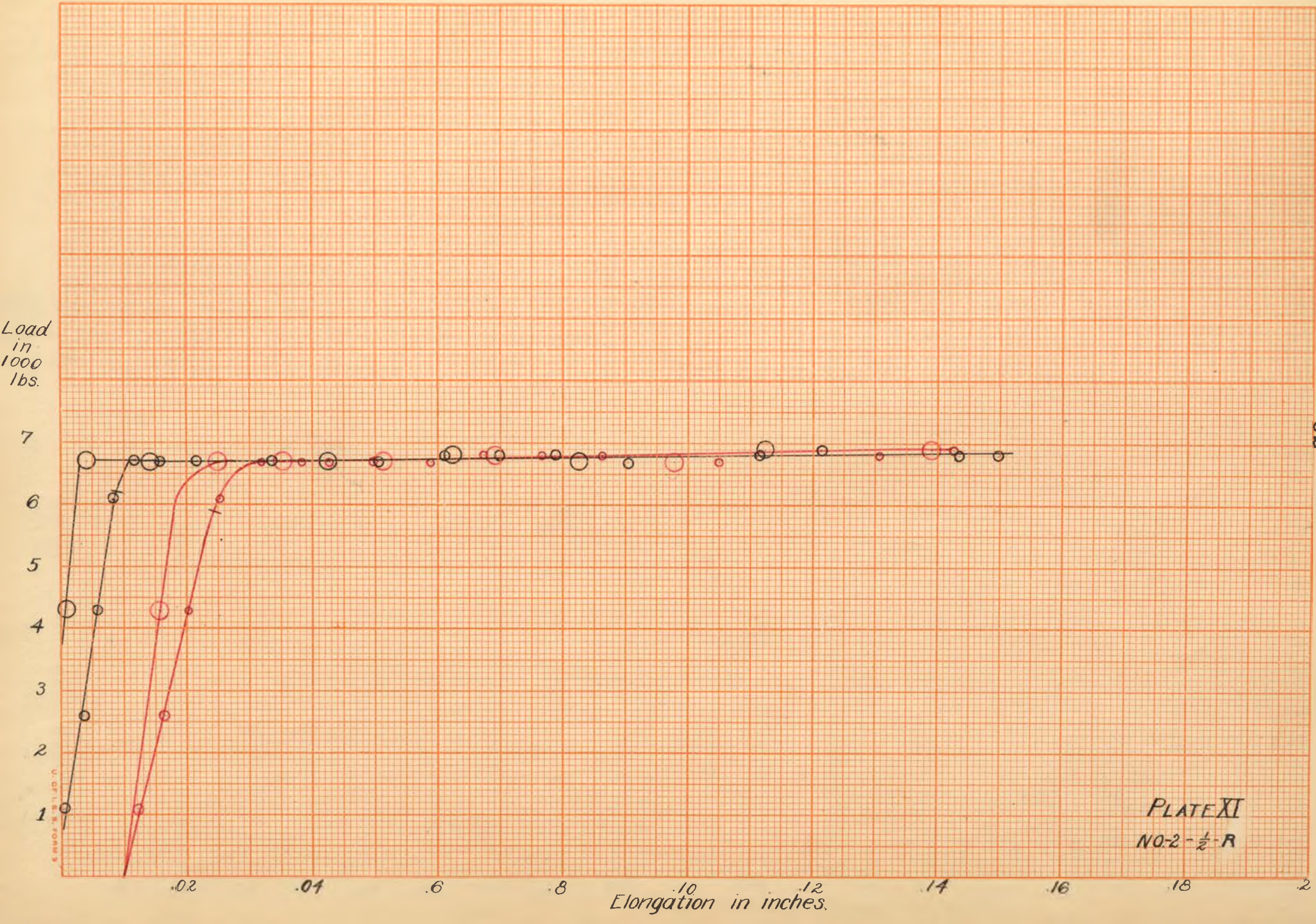
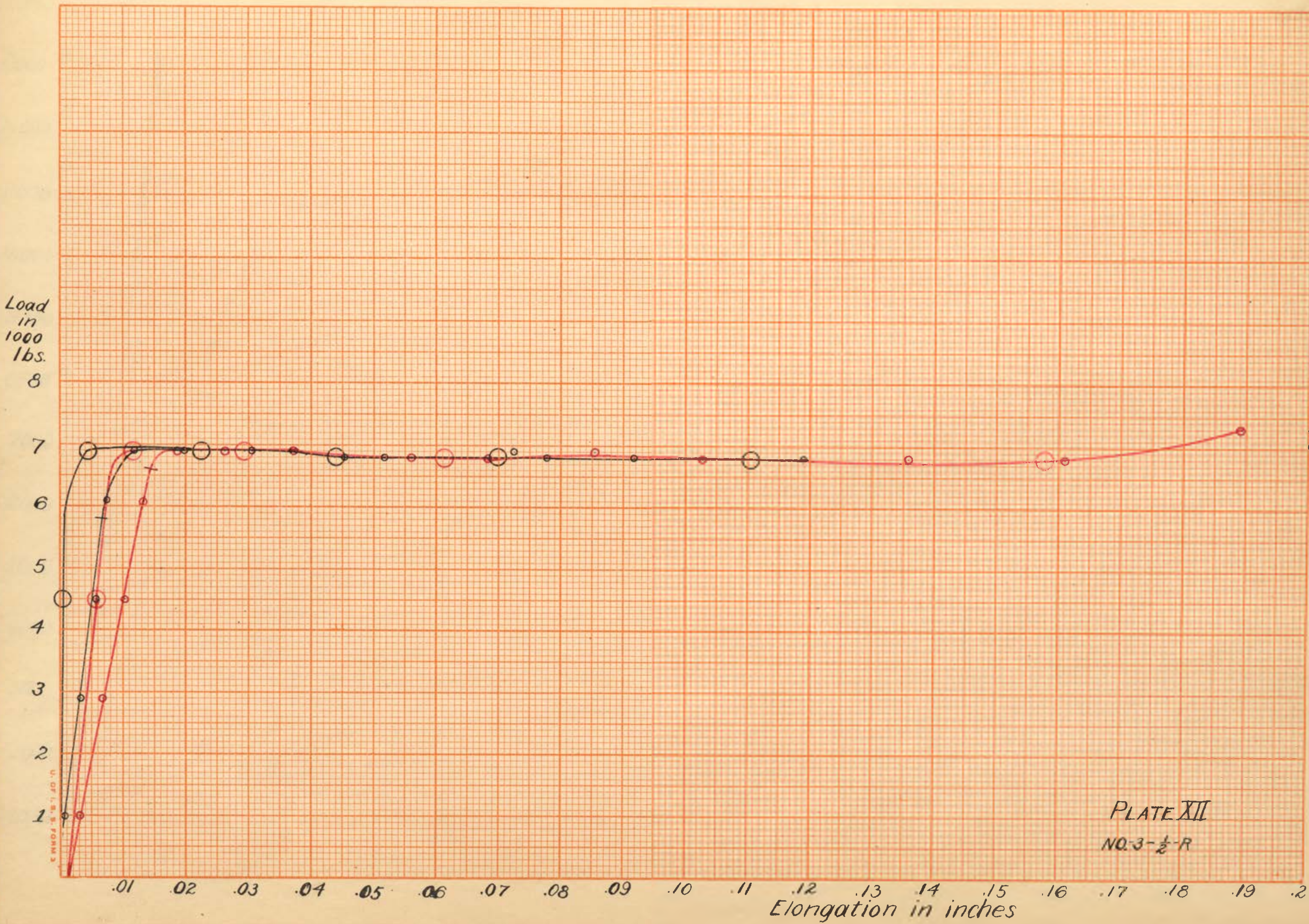


PLATE XI

NO-2 - ½ - R


Load in 1000 lbs.
8
7
6
5
4
3
2
1
.01
.02
.03
.04
.05
.06
.07
.08
.09
.10
.11
.12
.13
.14
.15
.16
.17
.18
.19
.2
Elongation in inches
PLATE XII
NO. 3-½-R

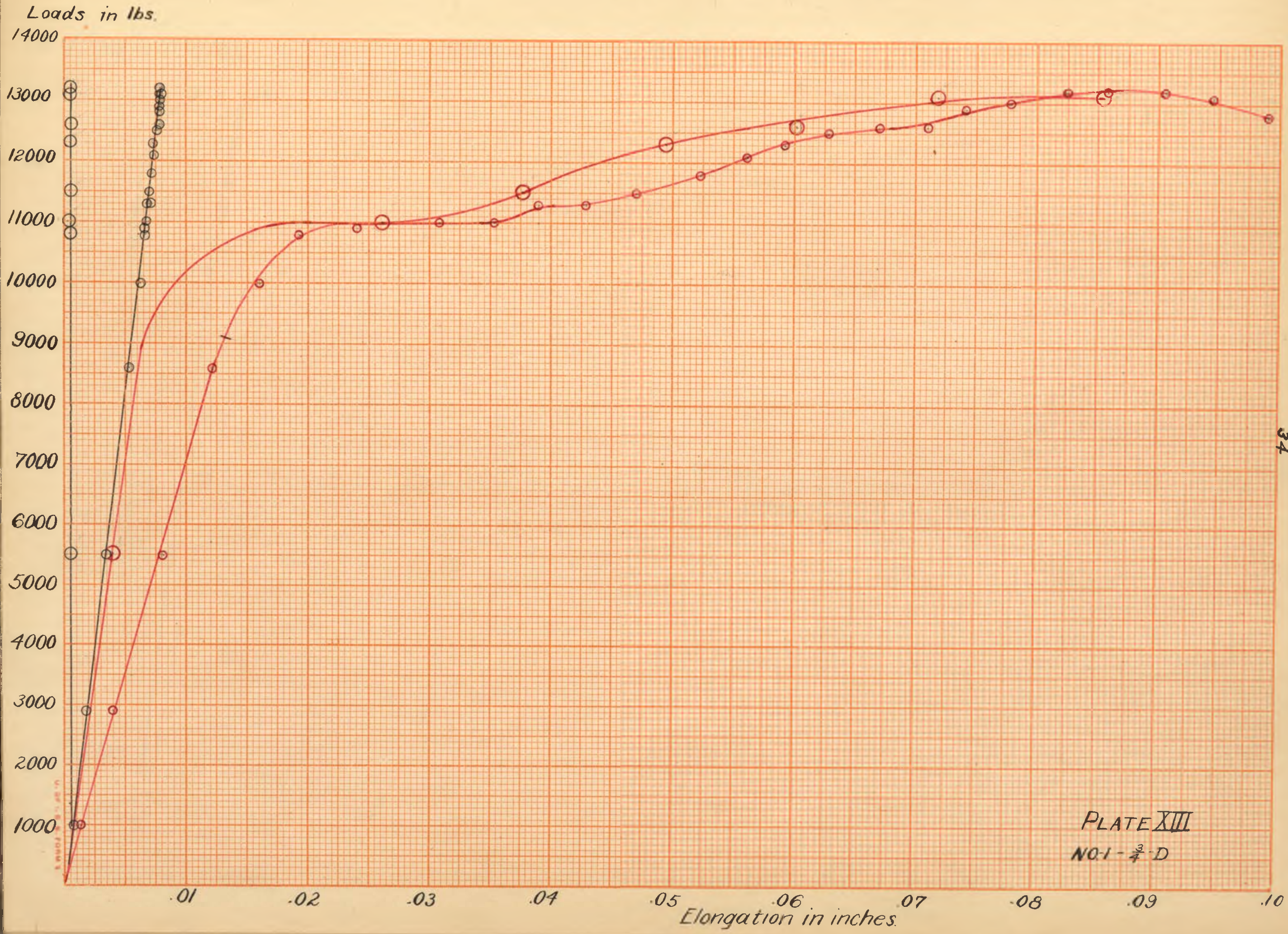
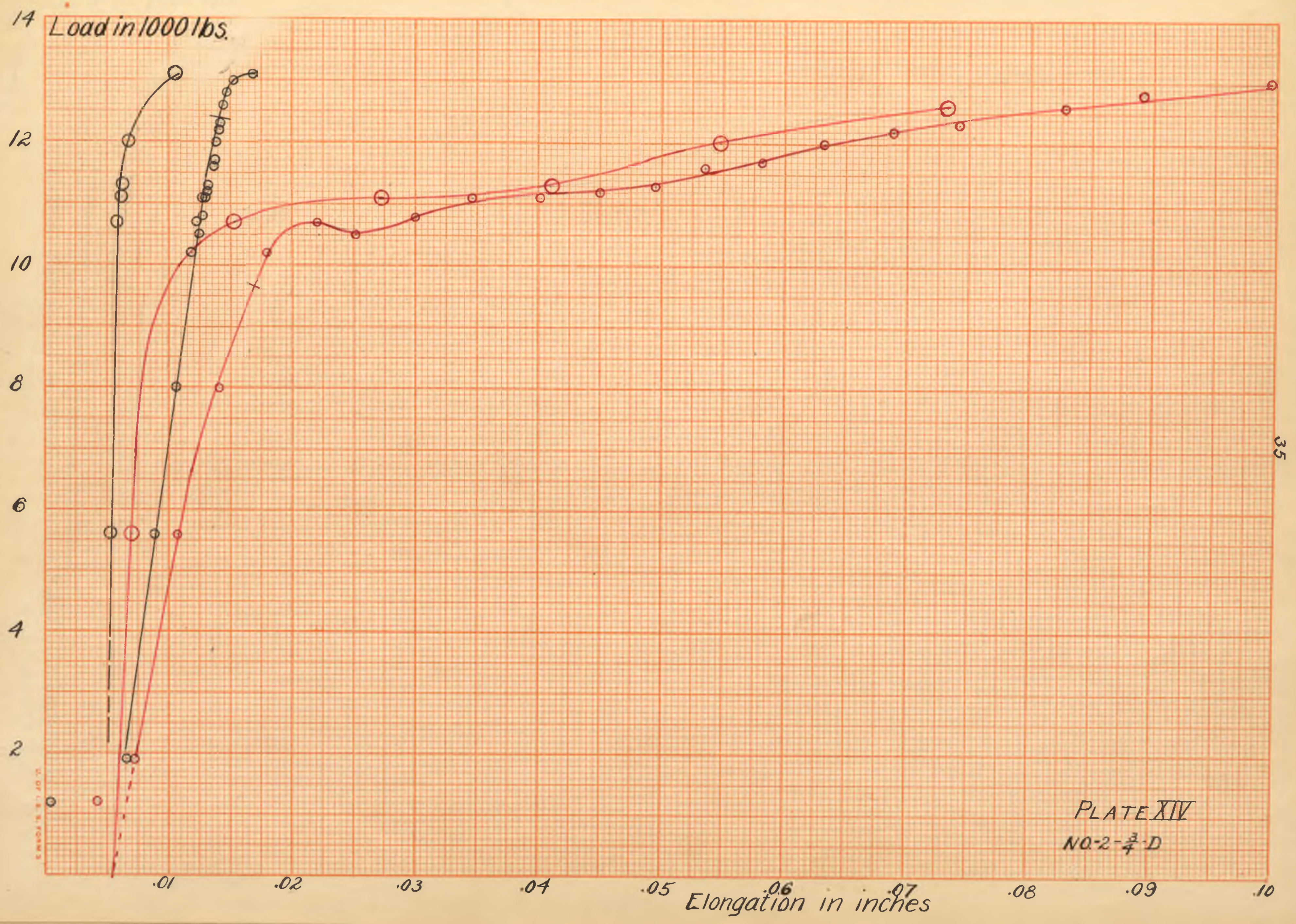
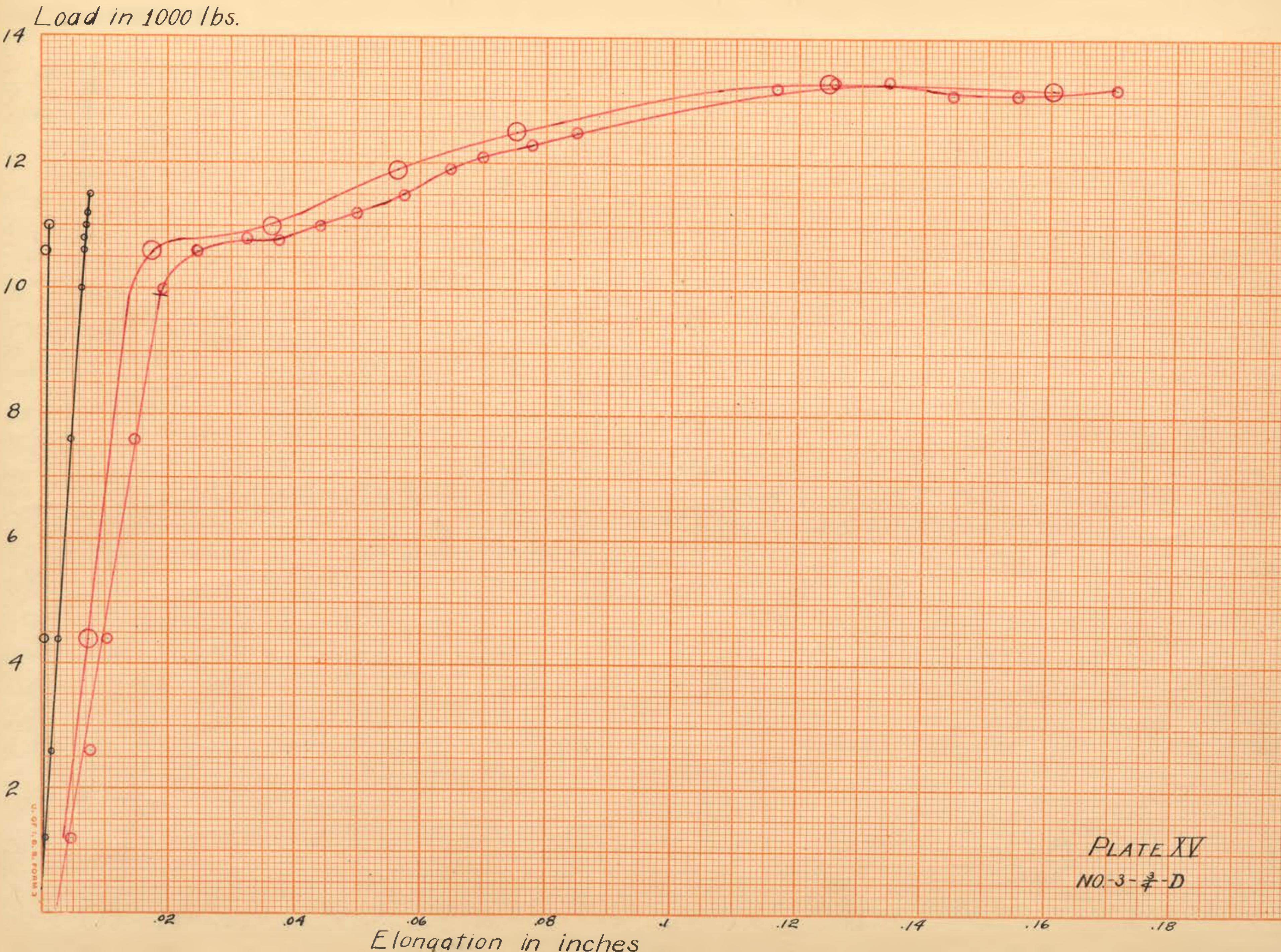


PLATE XIII

NO. 1 - $\frac{3}{4}$ - D



Load in 1000 lbs.
14
12
10
8
6
4
2
.01
.02
.03
.04
.05
.06
.07
.08
.09
.10
Elongation in inches
35
PLATE XIV
NO. 2 - 3/4 - D


Load in 1000 lbs.
14
12
10
8
6
4
2
.02
.04
.06
.08
.1
.12
.14
.16
.18
Elongation in inches
PLATE XV
NO.-3-¾-D

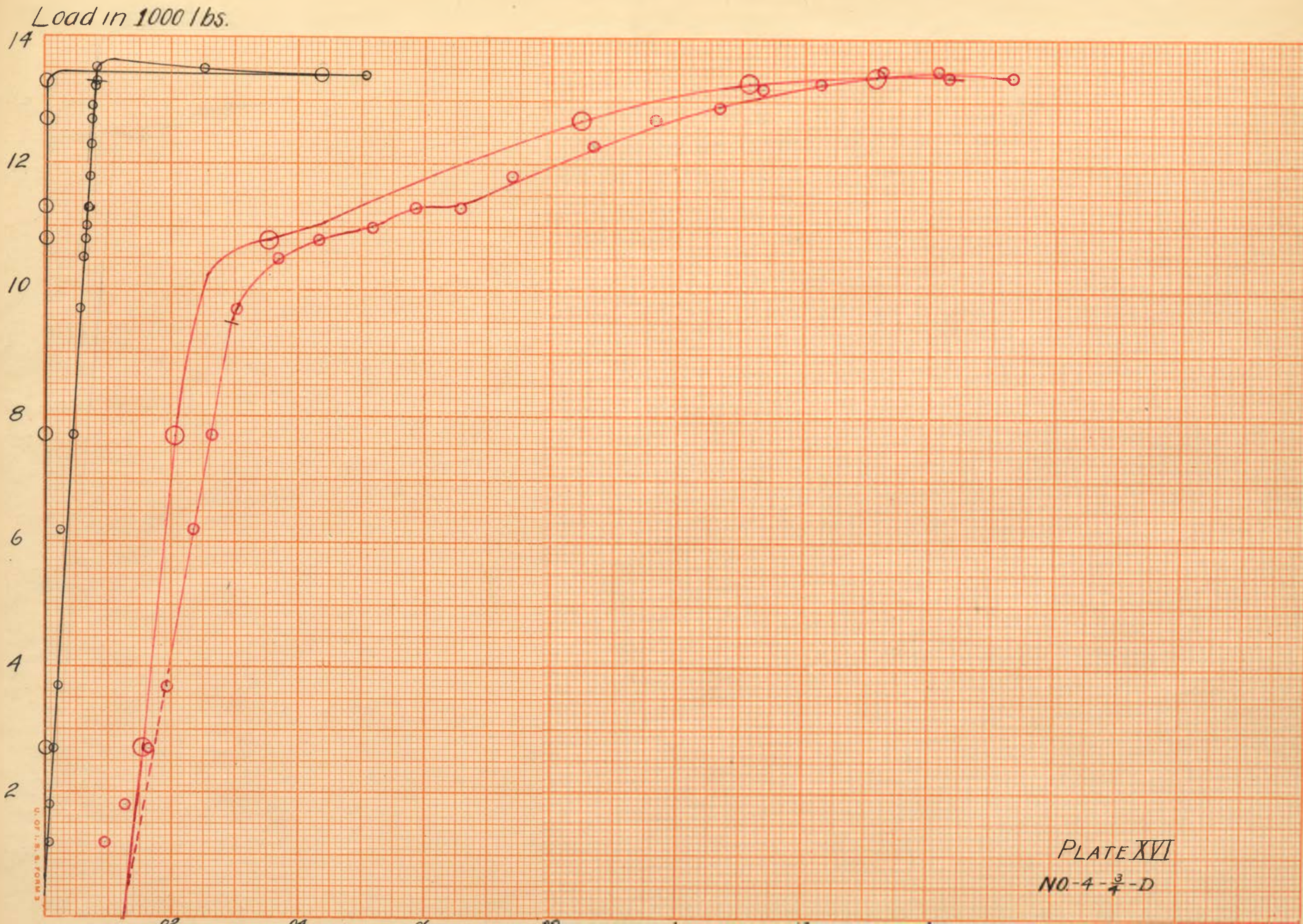
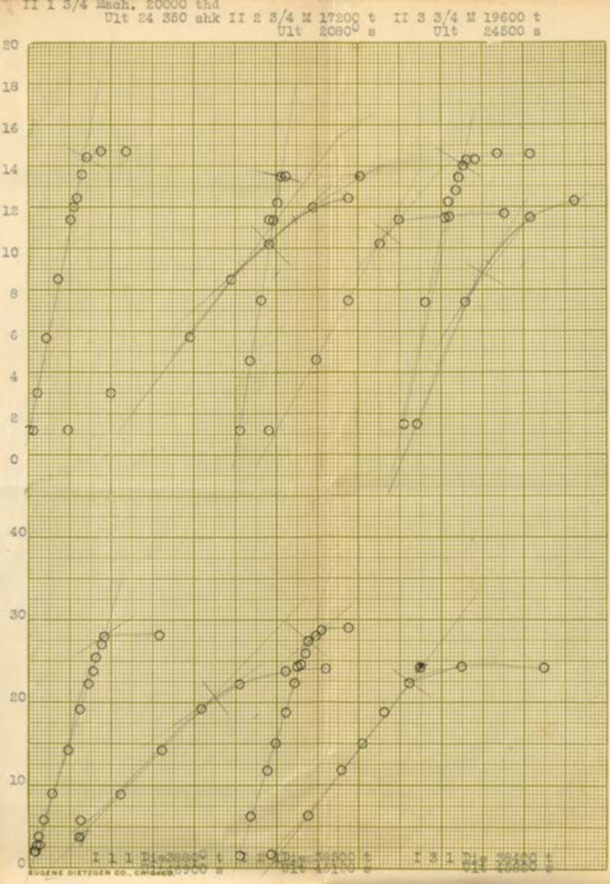

Load in 1000 lbs.
14
12
10
8
6
4
2
PLATE XVI
NO.-4-$\frac{3}{4}$-D

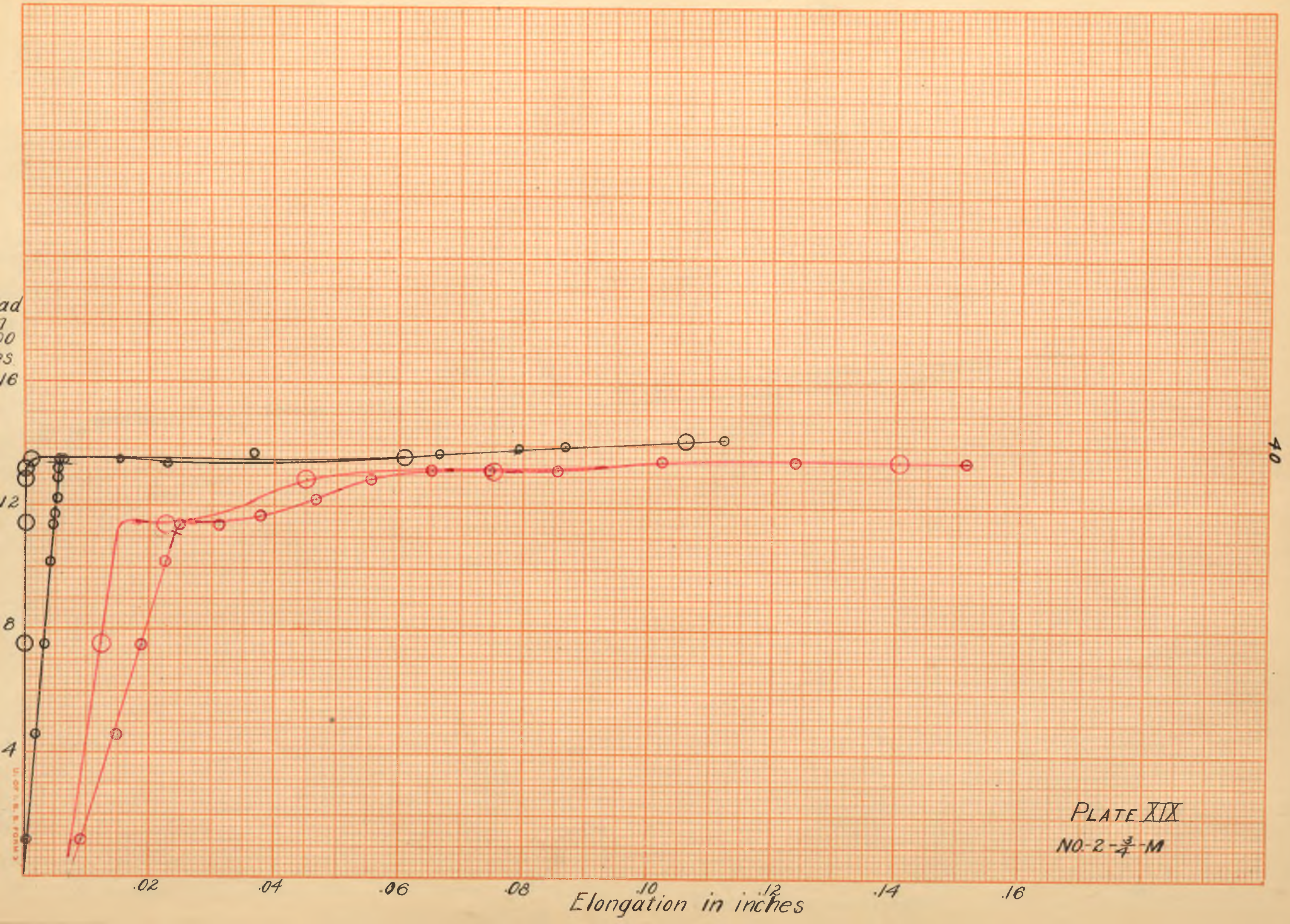
PLATE XVII

NO-5-$\frac{3}{4}$-D

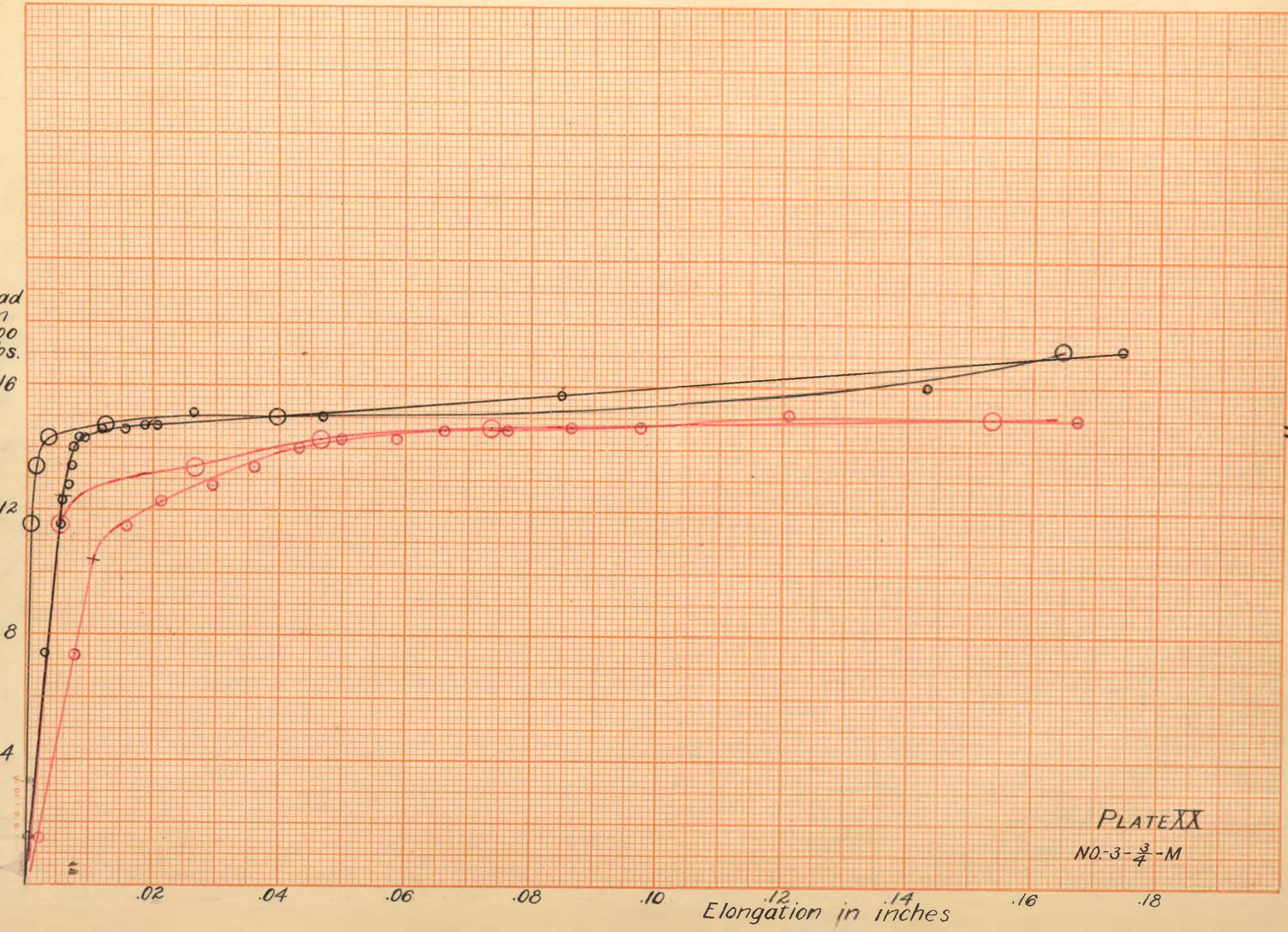
.02
.04
.06
.08
.10
.12
.14
Elongation in inches
PLATE XVIII
NO.-1-$\frac{3}{4}$-M

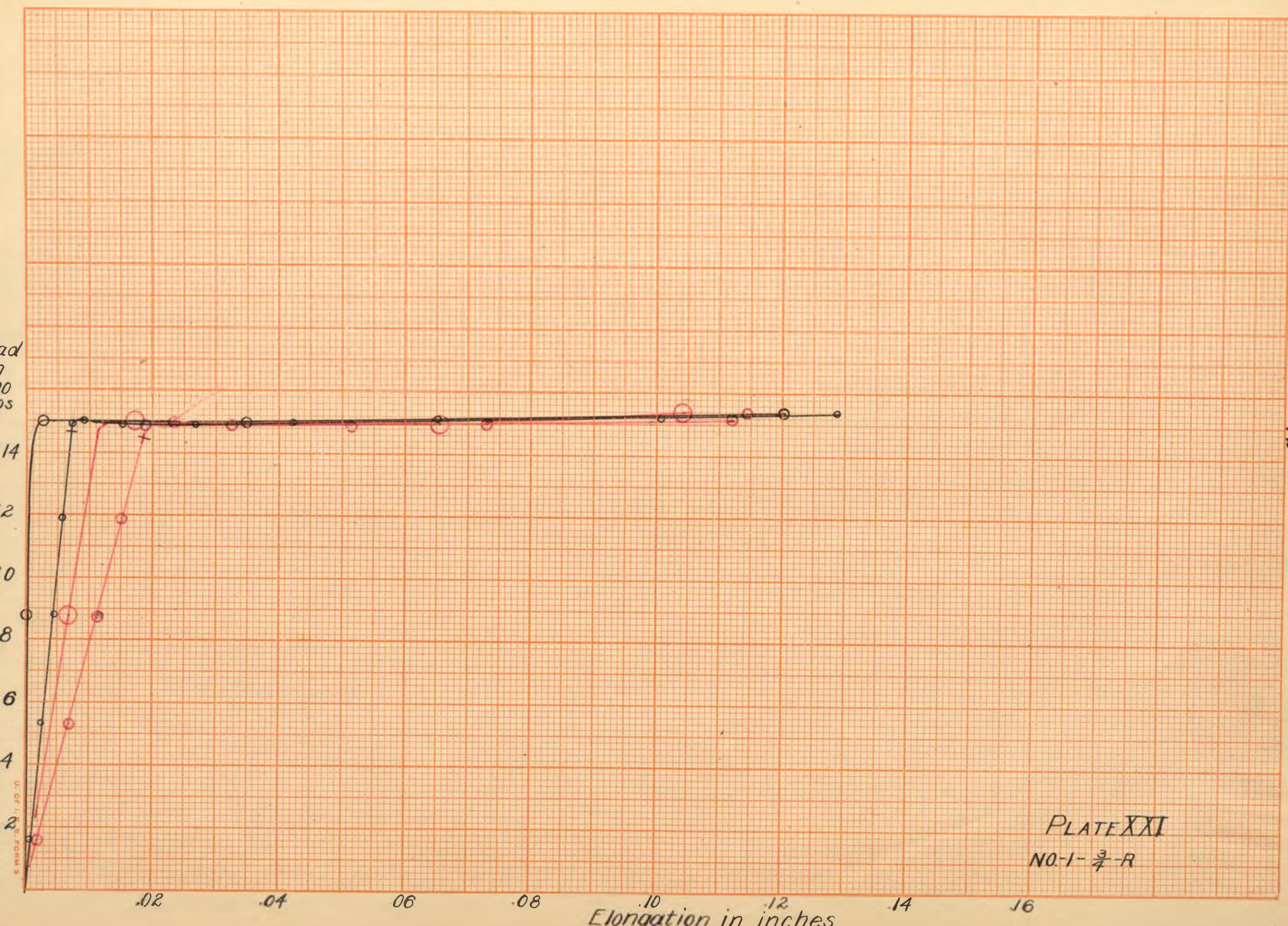

II 1 3/4 Mach. 20000 thd
Ult 24 350 shk II 2 3/4 M 17200 t
Ult 20800 s
II 3 3/4 M 19600 t
Ult 24500 s
20
18
16
14
12
10
8
6
4
2
0
40
30
20
10
0
EUGENE DIETZGEN CO., CHICAGO

Kind of Thread	No.	Nom'l Diam.	Actual Area Shank	Actual Area Root Thd.	Elastic Limit In Shank Load	Elastic Limit In Shank Stress	Elastic Limit In Shank Cor'd Load*	Elastic Limit In Thread Load	Elastic Limit In Thread Stress	Elastic Limit In Thread Cor'd Load*	Ultimate In Shank Load	Ultimate In Shank Stress	Ultimate In Shank Cor'd Load*	Ultimate In Thread Load	Ultimate In Thread Stress	Ultimate In Thread Cor'd Load*	Efficiency Ult.	Efficiency Elas Lim.
Die	1	1/2	—	~~.1257~~	—	—	[illegible]	—	—					10110	81000	~~8900~~	~~.798~~	
	2		.1924	.1353	7000	36400		4420	32700	4250	~~12000~~ 13100	68000		10290	76000	~~[illegible]~~ 9100	.797	631 703
	3		.1963	.1164	8200	41600	6880	6060	43500	4250	13000	66200		10370	89000	~~[illegible]~~ 9400	~~.793 .785~~	616 894
	4		.1924	.1257	6880	35800	6730	5220	41600	5100	12900	67100		10470	83500	9350	.805	759 653
	5		.1932	.1320	7100	36700	6770	5100	38500	4860	10900	56500		8400	63600	~~9200~~ 8950	.770	719 683
	6		.2003	.1340	6850	34200	7000	4260	32300	4360	10900	54400		8000	60400	8830	.733	623 659
	7		.1916	.1320	8050	42000	6700	5250	39700	4380	12900	67300		10250	77600	9150	.795	651 689
	8		.1987	.1257	7030	35500	6920	4230	33600	4170	10900	54900		8000	63800	8750	.733	601 632
	9		.1995	.1320	6600	~~[illegible]~~	7000	4780	36200	5060	10900	54500		8000	60400	8800	.733	723 652
	10		.1963	.1320	7450	38000	6860	5410	41000	4980	12900	65800		10200	77000	9300	.791	726 672
										4601						9070		
	1	3/4	.4324	.3019	13200	30400	15200	9100	30100	10500	21100	48600		16800	55600	20700	795	688 698
	2		.4359	3019	12800	29300	15250	9400	31100	11200	20800	47600		16300	54000	20500	784	735 692
	3		4359	.3019	11900	27250	15330	10000	33100	12800	21100	48400		14800	49000	18350	702	839 692
	4		4394	.3058	12250	27900	15370	? 5400		6800 ?	20800	47400		16700		21100	803	—
	5		4300	3019	13500	31400	15050	10200	33700	11400	20600	47900		16260	53800	20400	791	755 702
										11475						20210		
	1	1	.7667	.5542	28000	36500		20600	37200	19750	46900	61100		38800	70000	38100	828	735 721
	2		.7698	.5542	27500	35700		22500	40600	22100	46100	59800		38500	69500	38600	834	818 719
	3		.7854	.5542	—	—		—			45800	58400		38400	69300	39500	837	— 705
										20925						38730		
Machine	1	3/4	.4418	.3019	14400	32600		10250	34000	11000	24330	55200		20000	66200	21750	823	712 684
	2		.4383	.3019	13500	30750		10700	35500	12150	20800	47400		17200	57000	21750	.825	793 688
	3		4430	.3019	14000	31600		8800	29100	9750	24500	55300		19600	65000	~~35500~~ 21300	801	628 681
										10970						21600		
	1	1	.7729	.5542	24500	31700		17400	31400	19200	39300	50900		33300	60100	39300	845	709 716
	2		.7729	.5542	25700	33200		20600	37200	21700	45500	58900		38000	68500	38700	835	802 716
	3		7744	.5542	28200	36400		19800	35700	19050	45300	58500		38200	68900	39200	843	701 714
										19980						39070		
Rolled	1	1/2	.1562	1320	6610	42400		6650	67400	5500	9400	60000		8000	81000	9400	~~854~~	845
	2		1548	1320 .0982	6130	39600		6130	62100	5420	9440	61000		7900	80000	9250	Broke in Shank	854
	3		1590	1256	6100	38400		6190	62600	5640	9500	59800		8100	82000	~~9550~~		790
										5320						9400		
	1	3/4	.3761	.3117	14900	39600		14900	63400	13200	23400	62200		19730	84000	22400		828
	2		.3926	.3117	15000	38200		14400	61200	13200	23600	60200		18710	79500	23500		794
	3		.3870	.3117	15100	39000		15000	63800	13450	23700	61300		18660	79300	23200		805
										13283						23050		
	1	1	.6691	.5411	~~[illegible]~~	33750		16900	39200	17550 ?	36400	54500		34600	80300	40100		809
	2		.6720	.5411	23400	34800		22500	52200	22600	36400	52700		34600	80300	39400		805
	3		.6793	.5411	23600	34800		22600	52400	22700	36500	53750		34140	79200	38200		798
										22650						39230		



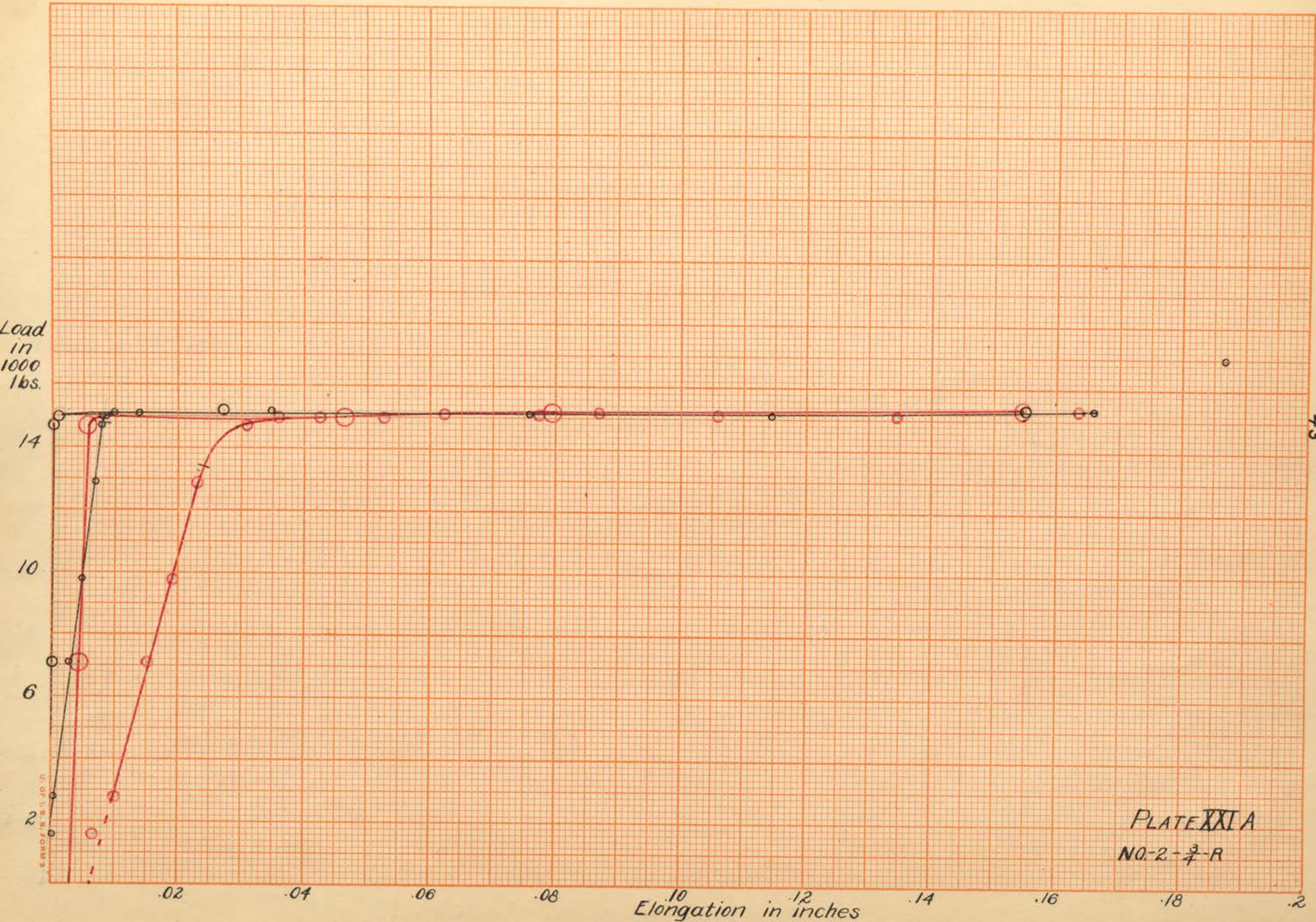
ad
n
00
s.
16
12
8
4
40
.02
.04
.06
.08
.10
.12
.14
.16
Elongation in inches
PLATE XIX
NO-2-¾-M


ad
n
00
bs.
16
12
8
4
.02
.04
.06
.08
.10
.12
.14
.16
.18
Elongation in inches
PLATE XX
NO.-3-$\frac{3}{4}$-M



ad
0
ps
14
2
0
8
6
4
2
.02
.04
.06
.08
.10
.12
.14
.16
Elongation in inches
PLATE XXI
NO. 1 - 3/4 - R

42



Load in 1000 lbs.
14
10
6
2
.02
.04
.06
.08
.10
.12
.14
.16
.18
.2
Elongation in inches
43
PLATE XXI A
NO.-2-3/4-R

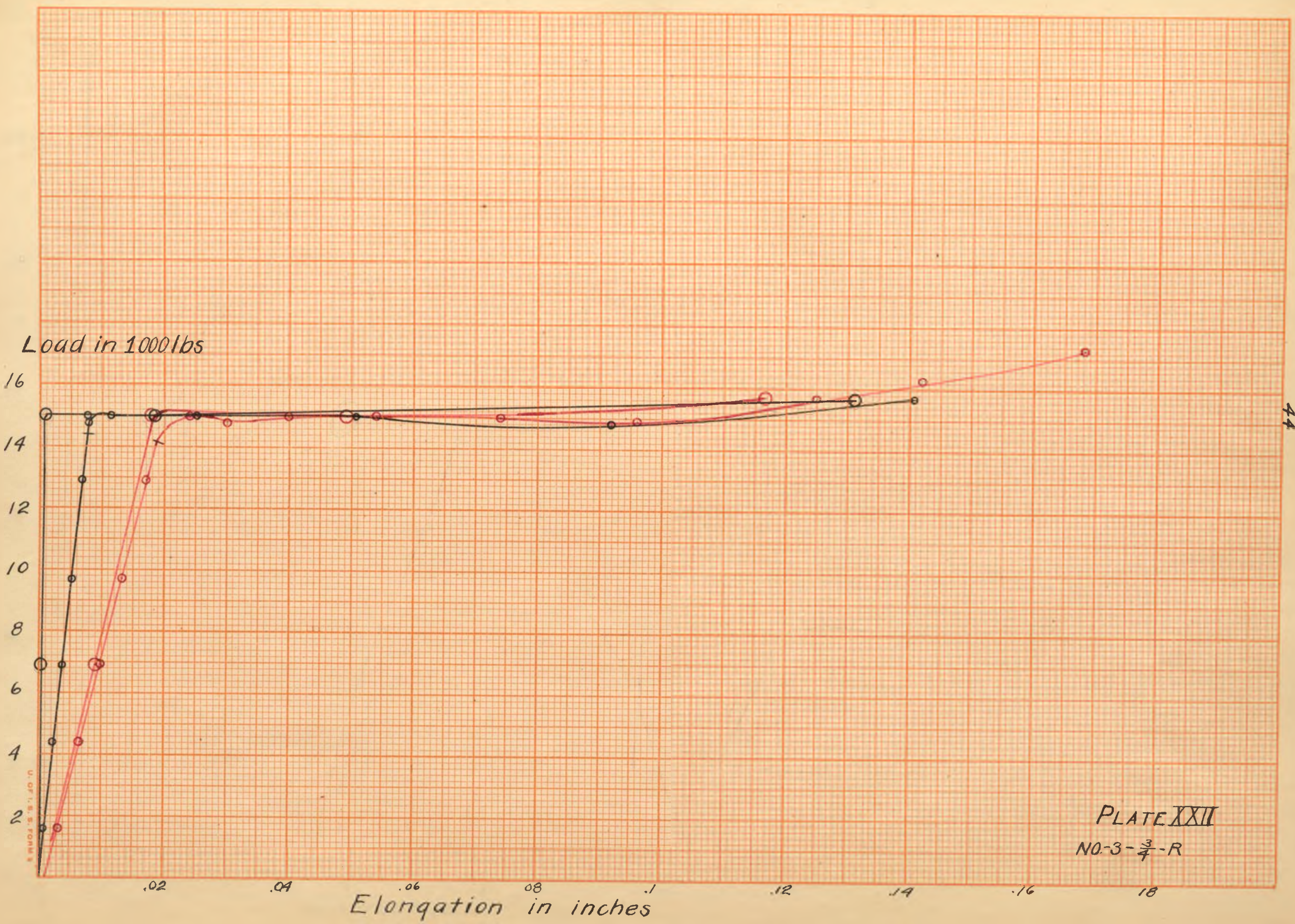


PLATE XXII

NO.-3-$\frac{3}{4}$-R

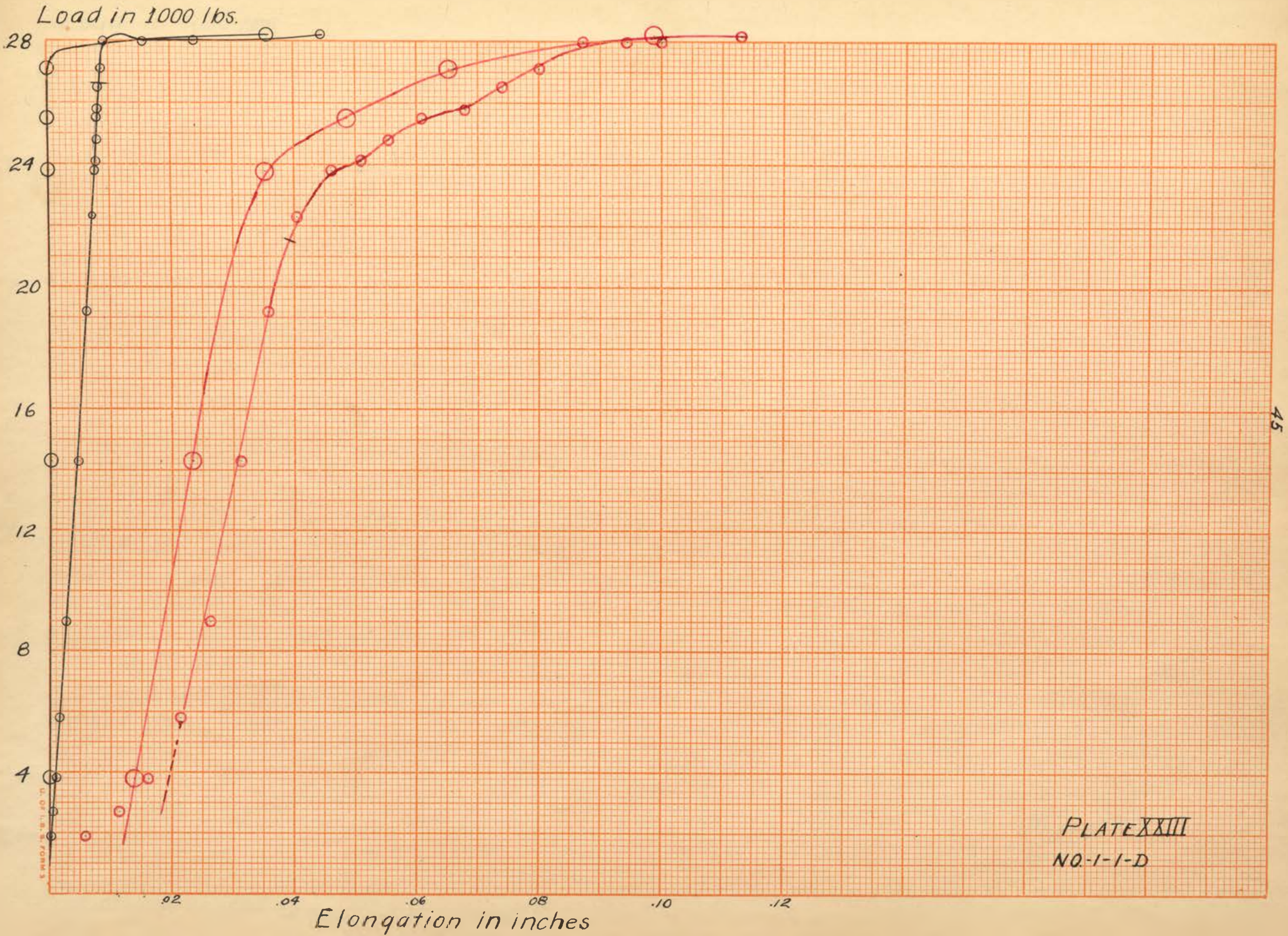
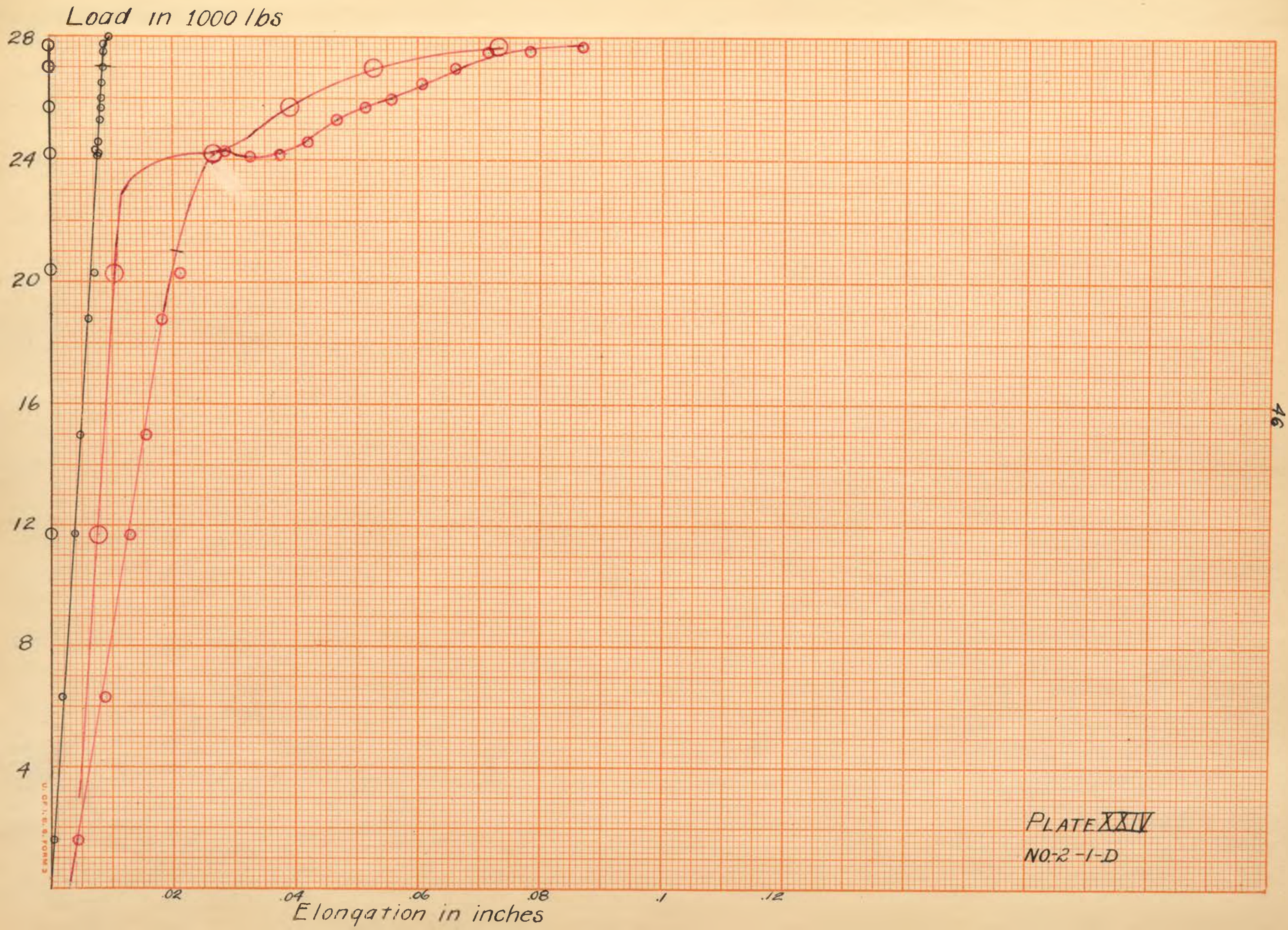
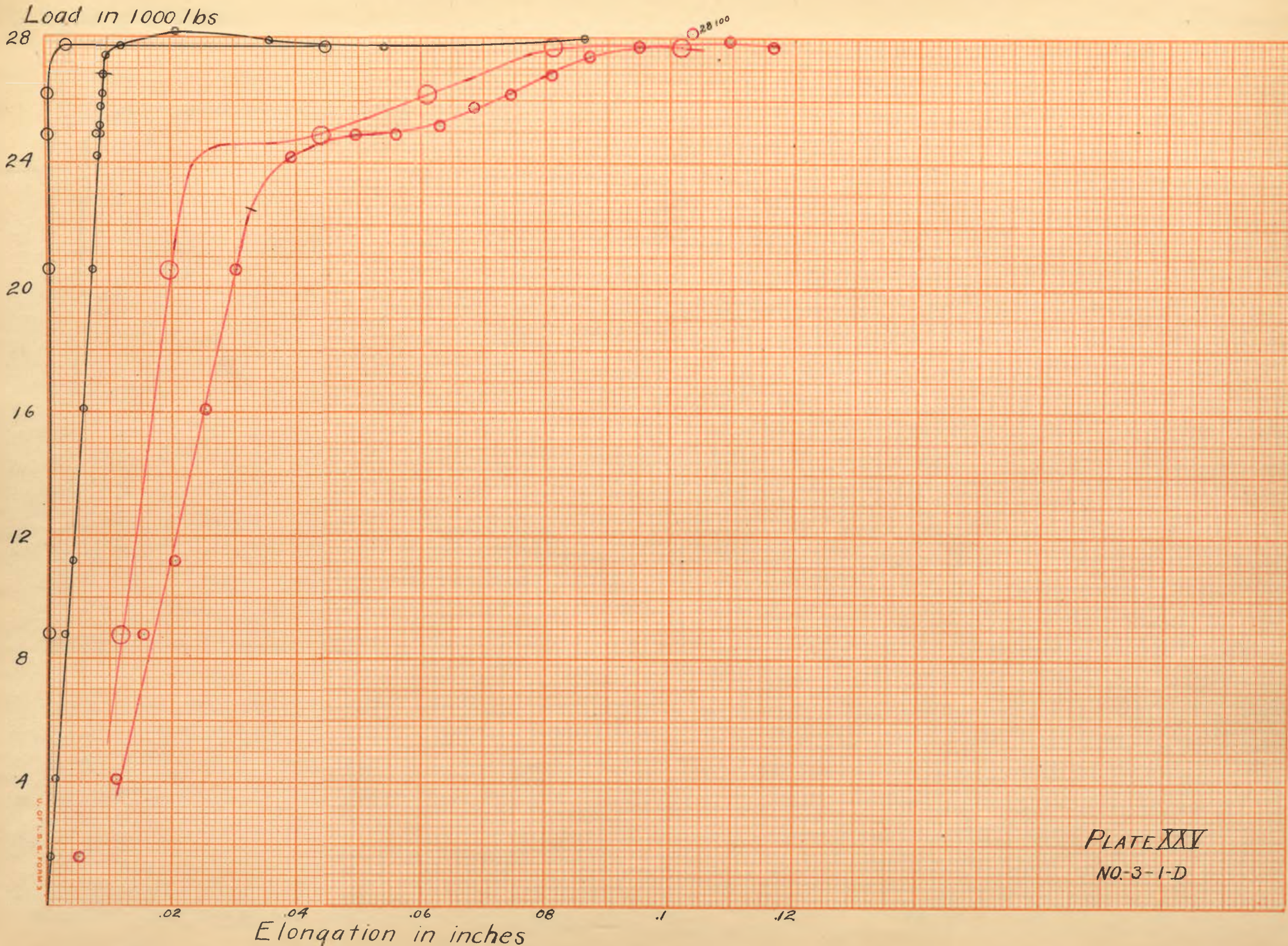
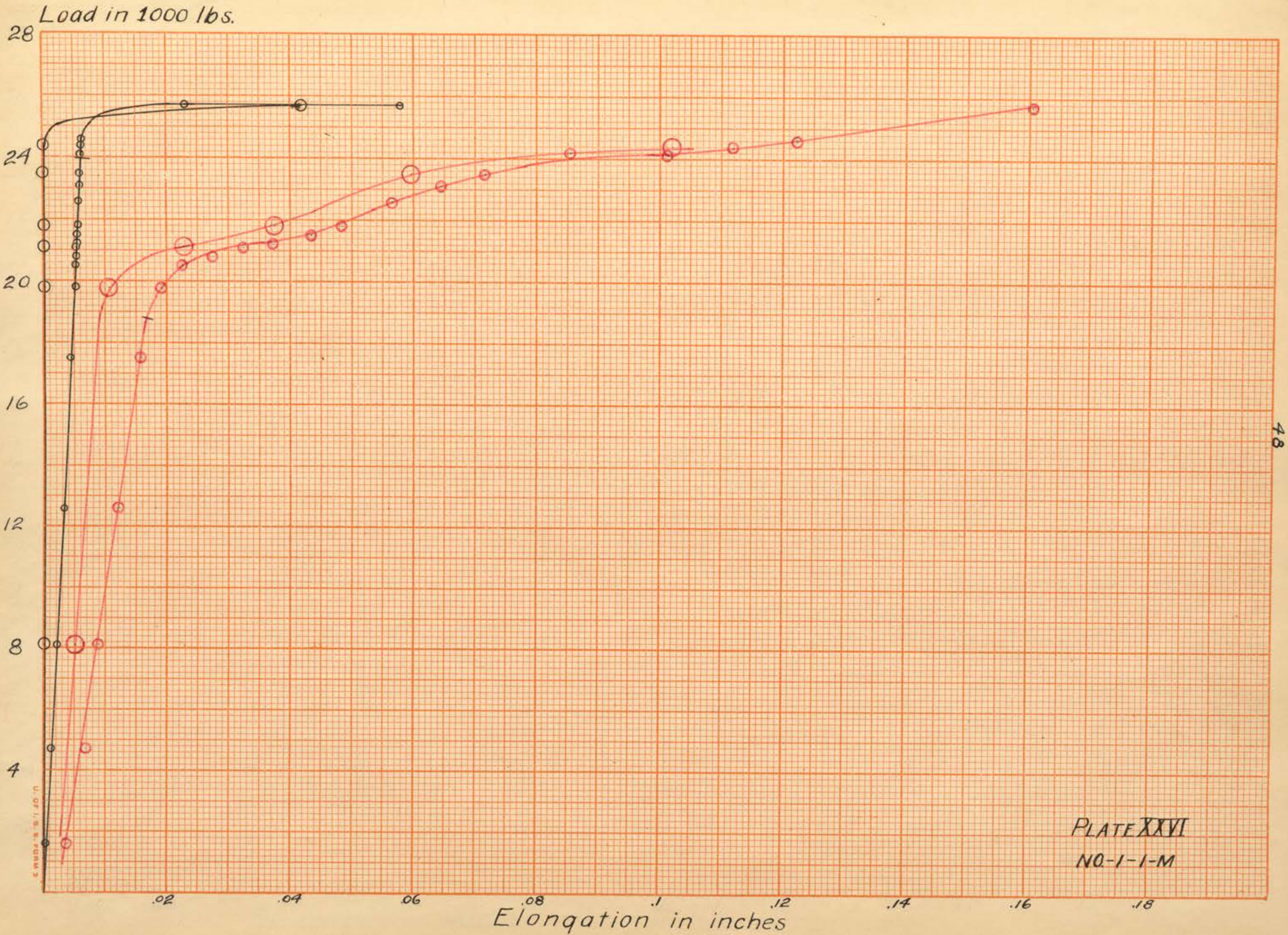


PLATE XXIII

NO.-1-1-D


Load in 1000 lbs
28
24
20
16
12
8
4
.02
.04
.06
.08
.1
.12
Elongation in inches
PLATE XXIV
NO-2-1-D
46


Load in 1000 lbs
28
24
20
16
12
8
4
.02
.04
.06
.08
.1
.12
Elongation in inches
28 100
PLATE XXV
NO.-3-1-D
U. OF I. S. S. FORM 3


Load in 1000 lbs.
28
24
20
16
12
8
4
.02
.04
.06
.08
.1
.12
.14
.16
.18
Elongation in inches
PLATE XXVI
NO-1-1-M
48

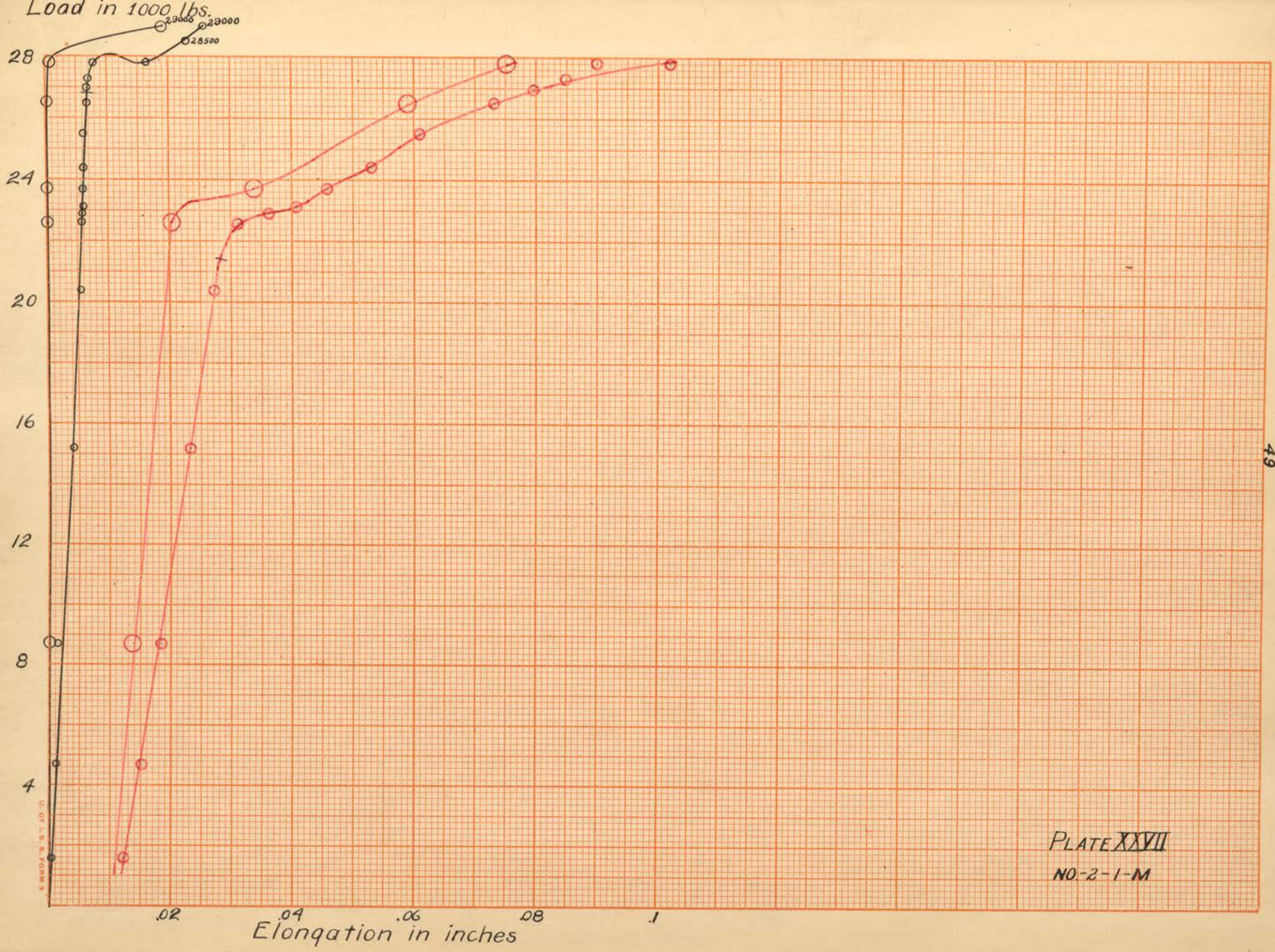


PLATE XXVII
NO.-2-1-M

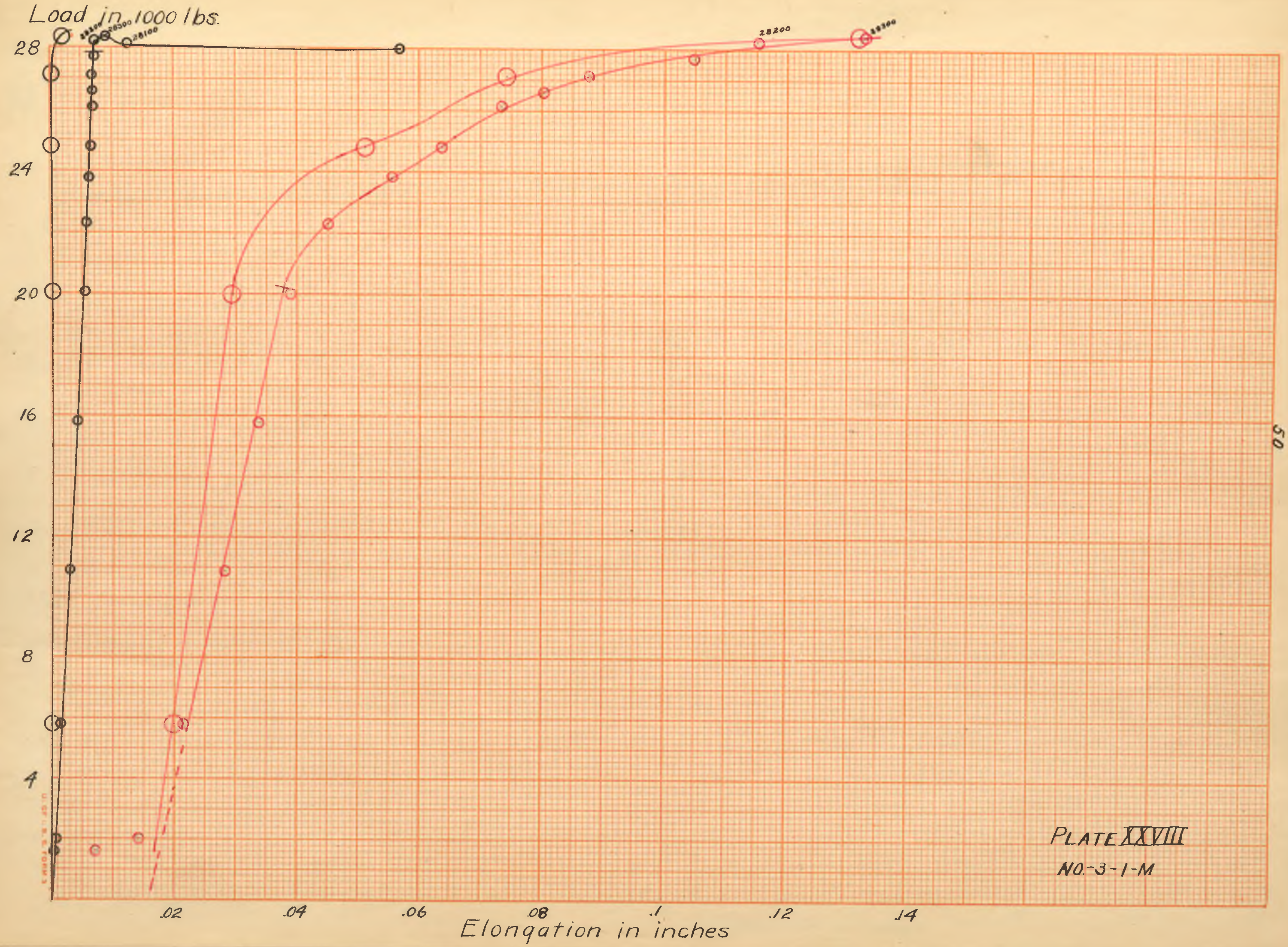


PLATE XXVIII
NO.-3-1-M

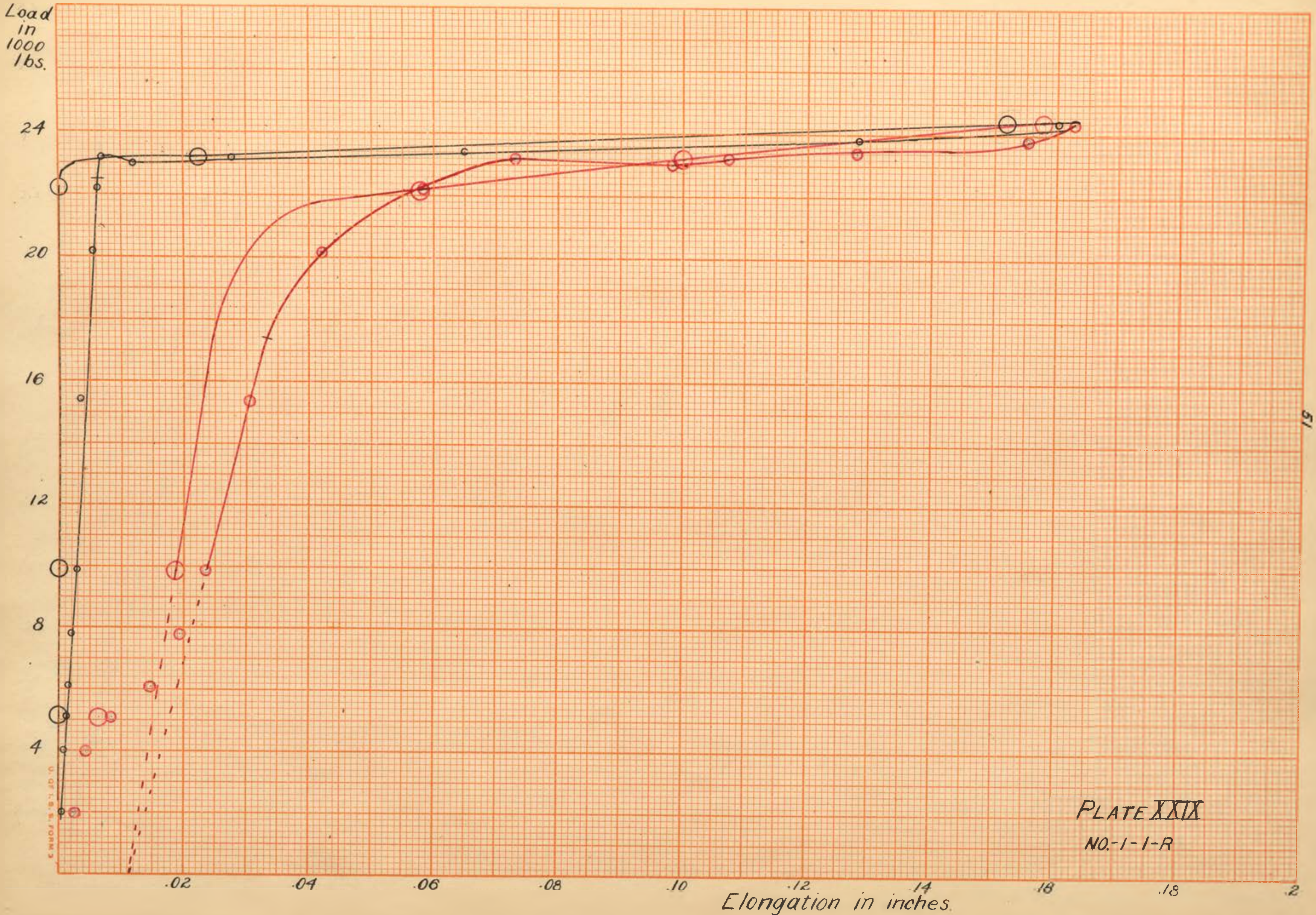
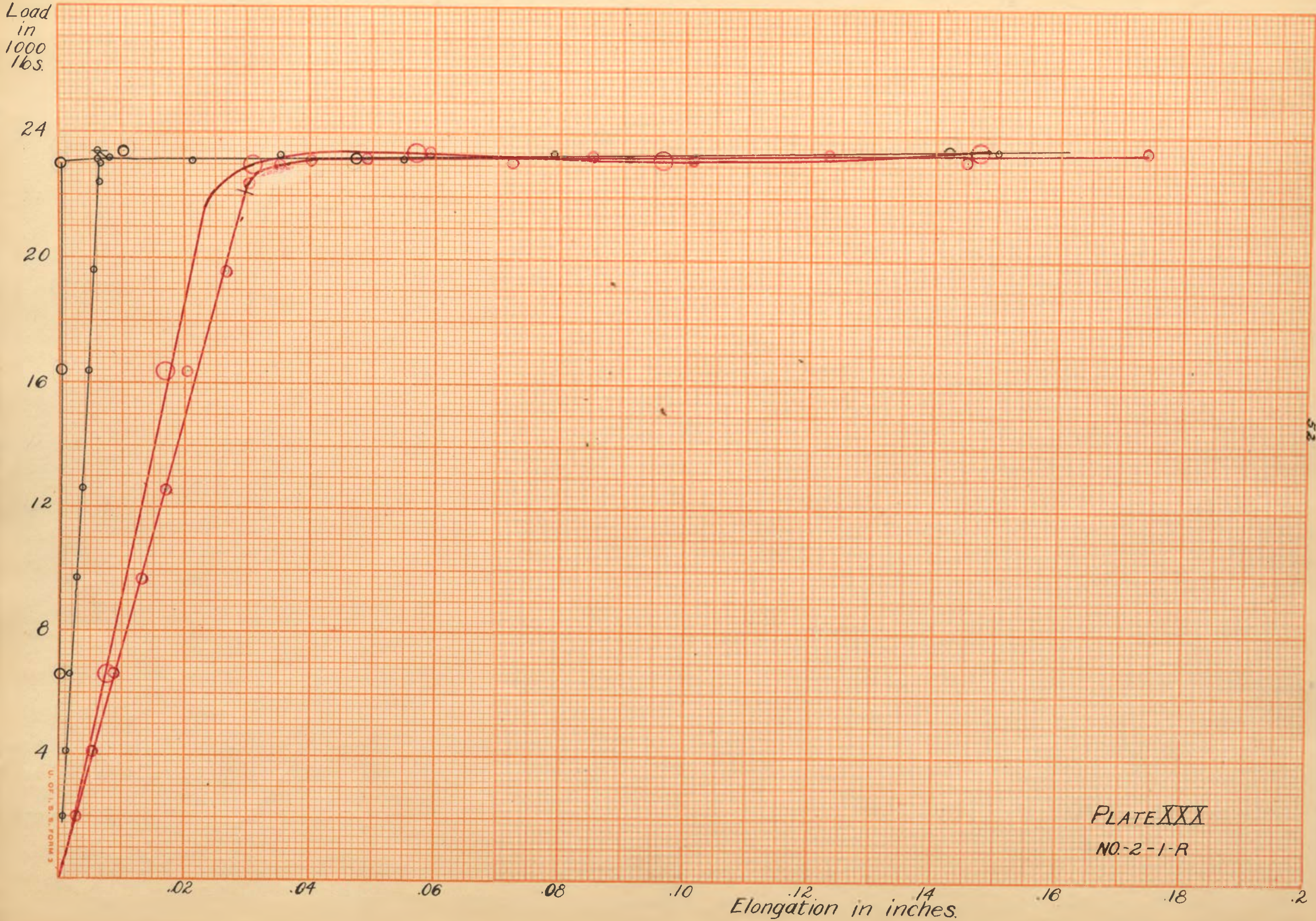


PLATE XXIX

NO.-1-1-R

51



Load in 1000 lbs.
24
20
16
12
8
4
.02
.04
.06
.08
.10
.12
.14
.16
.18
.2
Elongation in inches.
PLATE XXX
NO.-2-1-R

52

PLATE XXXI
NO. 3-1-R